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CONTENTS

Page

TDE Residues in Clear Lake Animals
Jack D. Linn and Ronald L. Stanley 164

The Influence of Soil Texture on the Structure, Durability, and Occupancy of Muskrat Burrows in Farm Ponds
Caroline M. Earhart 179

Life History Studies of the Lahontan Redside, *Richardsonius egregius*, in Lake Tahoe ---------------- *Douglas H. Evans* 197

Effects of Hydraulic Pumping Operations on the Fauna of Tijuana Slough ------------------------- *James R. Bybee* 213

A Survey of Helminth Parasites in the Squid, *Loligo opalescens*, Smelt, *Osmerus mordax*, Jack Mackerel, *Trachurus symmetricus*, and Pacific Mackerel, *Scomber japonicus*
Murray D. Dailey 221

Outbreak of Cryptocaryoniasis in Marine Aquaria at Scripps Institution of Oceanography
Donald W. Wilkie and Hillel Gordin 227

Notes

Desert Bighorn (*Ovis canadensis nelsoni*) Losses in a Natural Trap Tank ------------------------- *Jerry L. Mensch* 237

Occurrence of a Pacific Ridley and a Young Northern Fur Seal in Monterey Bay -------------- *G. Victor Morejohn* 239

The Addition of the Mirror Dory, *Zenopsis nebulosa* (Temminck and Schlegel), to the Californian Fauna
Paul Gregory 243

Northern Range Extension for *Paralepis atlantica* Kroyer in the Eastern North Pacific ------------ *Hiroshi Kajimura* 246

A Larval Cestode from the Pismo Clam, *Tivela stultorum*
Ronald W. Warner and Stanley C. Katkansky 248

Palaemonetes paludosus Collected in the Rio Hardy and Colorado River, Baja California
James A. St. Amant and Robert G. Hulquist 252

Book Reviews -- 253

ERRATUM

Mitchell, Charles T., Charles H. Turner, and Alec R. Strachan. Observations on the biology and behavior of the California spiny lobster, *Panulirus interruptus* (Randall). 55 (2) : 121–131. 1969.

The statistic for the regression line in Figure 9 (page 129) should read:

$$Y = 5.32 + .886X$$

Calif. Fish and Game, 55(3) : 164–178. 1969.

TDE RESIDUES IN CLEAR LAKE ANIMALS[1]

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A cooperative program to monitor the levels of TDE residues in Clear Lake fauna was conducted from 1959 through 1965. Eight species of fishes and four species of birds were collected for residue analysis, though primary emphasis was on largemouth bass and white catfish. Residues of TDE varied considerably among individual animals, but the general level of contamination in birds and fish declined from the high levels reported in 1958 to much lower levels in 1963 and 1965.

INTRODUCTION

The accumulation of TDE (tetrachloro-diphenyl-ethane), also known as DDD (dichloro-diphenyl-dichlorethane), in the biota of Clear Lake is an example of biological concentration of a fat soluble chlorinated hydrocarbon pesticide within components of an ecosystem. The study reported by Hunt and Bischoff (1960) documented that residues had accumulated in fish and aquatic birds after three applications of TDE to the water of the lake within a 10-year period for gnat control. The chemical concentrate was applied to the lake at a rate to produce a concentration of 0.014 ppm for the first application and 0.02 ppm for the last two applications. Residues in excess of 1,000 ppm TDE in the fat of some individual fish and birds were reported one year after the last application to the lake. Circumstantial evidence suggested that die-offs of western grebes and a decline of grebe nesting populations was related to the accumulation of TDE residues in their body tissues. There were no large-scale fish die-offs, although maximum residues in catfish and largemouth bass were as high as or higher than those in grebes. Residues in other fish were lower than in grebes.

The high residues found in game fish indicated a possible public health hazard through consumption of fish from the lake. A program was developed to study the public health implications associated with the residues in the sport-fish catch. Toxicologists concluded that at the levels found the residue in edible fish flesh did not pose an acute hazard to persons eating the fish. It was not known if the level would increase or decrease in future years. Therefore, it was agreed that the Department of Fish and Game would continue to collect samples and the Department of Public Health would analyze them to establish the trend of residue levels. No additional applications of TDE or related pesticides have been made to the lake water for gnat control. Subsequent chemical treatments have been made with methyl parathion and no apparent fish or wildlife problems have developed.

[1] Accepted for publication December 1968. This study was supported by Federal Aid in Fish and Wildlife Restoration Project FW-1-R, "Pesticides Investigations".

The Department of Fish and Game collected samples each year from 1957 through 1963 and in 1965. No samples were collected in 1964. Instead, the two agencies reviewed the study and decided to terminate it with an intensive collection of white catfish in 1965, if the level of TDE remained low.

The samples were analyzed for TDE by the Department of Public Health. The data for 1957 and 1958 were reported by Hunt and Bischoff (1960). This paper presents the data obtained since 1958 and discusses the trend in residue levels.

SAMPLE COLLECTION

Thirteen separate collections were made: two in 1959, three in 1960, two in 1961, one in 1962, three in 1963, and two in 1965. Eight species of fishes, four species of birds, and a plankton sample were collected. The fish—largemouth bass, *Micropterus salmoides;* white catfish, *Ictalurus catus;* brown bullhead, *Ictalurus nebulosus;* black crappie, *Pomoxis nigromaculatus;* green sunfish, *Lepomis cyanellus;* Sacramento perch, *Archoplites interruptus;* Sacramento blackfish, *Orthodon microlepidotus;* and Sacramento hitch, *Lavina exilicauda*—were collected by seine, gill nets, fyke nets, set lines, and angling. The birds—western grebe, *Aechmophorus occidentalis;* gulls, *Larus* spp.; common goldeneye, *Bucephala clangula;* and common merganser, *Mergus merganser*—were collected by shooting. The single plankton sample was collected in 1959 with a conventional plankton net. Pesticide quantities in the samples are reported in Tables 1 through 13.

TABLE 1

Analysis of Tissue From Collection Made in April 1959

Species	Age	Year class	Number in sample	TDE (ppm)	
				Flesh	Fat
Largemouth bass	I	1958	4	11	
	I	1958	3	18	
	IV	1955	1	31	
White catfish	II	1957	1	23	
	III	1956	5	37	
	IV	1955	5	51	
	V	1954	4	62	
	VII	1952	2	77	
	IX	1950	1	184	
Black crappie	I	1958	6	14*	
	II	1957	2	10	
	III	1956	2	16	
Green sunfish	III	1956	1	2	103
Sacramento perch	IV	1955	1	316	3,972
Sacramento blackfish	--	--	13	7	

* This sample was run in duplicate. One analysis showed 14 ppm and the second showed 11 ppm. Thus, replicability at this level for the colorimetric method is about ± 10%.

Fish and birds were frozen soon after collection. At a later date they were examined to determine age, and subsamples of flesh tissue and fatty tissue were submitted to the laboratory for analysis. Some samples were from individual animals and others were composite samples. Residues are reported on a wet weight basis.

TABLE 2

Analysis of Tissue From Collection Made in October 1959

Species	Age	Year class	Number in sample	TDE (ppm)	
				Flesh	Fat
Largemouth bass	O	1959	15	4.4	
	I	1958	18	20.4	
	O	1959	4	--	437
	O	1959	4	--	449
	O	1959	1	--	360
White catfish	I	1958	3	9.4	
	II	1957	4	11.7	
	III	1956	4	9.5	
	IV	1955	1	18.7	
	IV	1955	1	16.2	
	IV	1955	1	16.7	
	IV	1955	1	33.4	
	IV	1955	1	18.3	
	V	1954	1	39.2	
	V	1954	1	37.5	
	V	1954	1	30.3	
	V	1954	1	26.9	
	V	1954	1	18.0	
	VI	1953	1	37.2	
	VI	1953	1	40.4	1,387
	VI	1953	1	43.5	
	VI	1953	1	18.5	
	I-IV	--	2	--	419
Black crappie	I	1958	1	11.0	460
	II	1957	1	24.1	
	III	1956	1	19.0	
Gull	--	--	12	--	2,134
Western grebe	--	--	5	--	1,465
Plankton	--	--	--	10.9*	

* Subject to an error of ± 100%, since the determination was made on a very small sample at the limit of sensitivity of the method.

Age of most fish was determined by counting the annuli on their scales. The catfish prior to the 1967 collection were "aged" by counting the annual rings on their vertebrae. The catfish in the 1965 collection were "aged" by counting the annual rings on pectoral spines sectioned by the method of Andrews (1963). Birds were classified as adults or immatures.

ANALYTICAL PROCEDURES

The pesticides were isolated from all samples by the method of Stanley and LeFavoure (1965), which was previously developed in the Food and Drug Laboratory of the Department of Public Health. Before 1962, quantitation was by the colorimetric method of Schechter,

TABLE 3

Analysis of Tissue From Collections Made in January and March 1960

Species	Age	Year class	Number in sample	TDE (ppm)	
				Flesh	Fat
Largemouth bass	II	1958	7	10	
	III	1957	1	9	
	IV	1956	1	21	
	V	1955	1	111	
	VI	1954	1	6	
White catfish	II	1958	2	2	
	III	1957	1	<5	
	IV	1956	1	15	
	V	1955	1	14	
	IX	1951	1	28	
	X	1950	1	20	
Brown bullhead	II	1958	1	<5	
	III	1957	1	4	
	III	1957	--	<1	
	IV	1956	2	2	
Sacramento blackfish	I	1959	3	1	
	II	1958	9	2	
	III	1957	1	1	
Hitch	I	1959	8	2	
	II	1958	5	<1	
Western grebe	--	--	1	--	825
	--	--	1	--	51
	--	--	1	--	527

Pogorelskin, and Haller (1947). Thereafter, quantitation was by electron capture gas chromatography. The methods of quantitation were compared in 1962 (Table 8) to determine the relative sensitivity of the two methods. Fat quantities were estimated by the method of Stanley and LeFavoure (1965). No detectable degradation of p,p'DDT was noted in the gas chromatograph.

The colorimetric method used for quantitation before 1962 fails to distinguish between TDE and DDT. It also fails to differentiate DDE from TDE ethylene, the dehydrochlorinated metabolite of TDE, whereas electron capture gas chromatography does make these distinctions.

When checked by gas chromatography, only one fish sample contained a detectable amount of DDT at a 1 ppm sensitivity level. DDT was present in detectable amounts in migratory birds but was not routinely quantitated.

DISCUSSION

There is no well-defined trend in the residue levels from year to year when all analyses are examined together. There is a wide variability of residues among individual animals collected at the same time, as well as among those collected in different years. Since the sampling program was not designed for statistical analysis, certain reservations must be placed on conclusions based on these data.

Forty-one grebes and 32 gulls were collected from 1959 through 1963 (Table 11). The grebes generally contained higher residue levels than gulls. This may be a reflection of food habits, since the grebes at the lake are restricted to a diet of fish, while the gulls are able to forage at various other food sources. Residue data for other waterfowl are insufficient to make realistic comparisons.

Five grebes collected in 1962 contained TDE residue in fatty tissue greater than 1,600 ppm. Moribund grebes containing TDE residues of a similar level of magnitude were collected in 1957 (Hunt and Bischoff, 1960). The moribund condition of these birds was diagnosed as chronic TDE poisoning. The grebes in the 1962 collection were in good health at the time they were collected and showed no symptoms of intoxication. No grebe die-offs have been recorded at Clear Lake since 1957.

The trend of TDE residues in Clear Lake animals is probably best assessed by examining the data for largemouth bass and white catfish. These two species were sampled each year through 1963 and white catfish were sampled in 1965. The yearly mean TDE residue in largemouth

TABLE 4

Analysis of Tissue From Collection Made in July 1960

Species	Age	Year class	Number in sample	TDE (ppm)	
				Flesh	Fat
Largemouth bass	II	1958	17	14	
White catfish	IV	1956	3	3	
	V	1955	4	12	
	VI	1954	1	5	
	VII	1953	1	47	
	VIII	1952	4	30	
	IX	1951	3	23	
	X	1950	3	45	
	XII	1948	1	22	
	IV	1956	2	--	118
	VIII	1952	1	--	<80
	X	1950	1	--	715
Brown bullhead	III	1957	2	<1	
Gull (adult)	--	--	3	--	<80
(immature)	--	--	3	--	<80
Western grebe	--	--	6	--	1,150

bass flesh tissue decreased from 40.9 ppm in 1958 to 13.7 ppm in 1959 (Table 12). Since 1959 the mean residue level appears to have been relatively stable.

The mean annual TDE residue in white catfish flesh tissue (Table 13) decreased from 85.7 ppm in 1958 to 10.2 ppm in 1960, increased to 44.9 ppm in 1962, then decreased again, reaching the approximate 1960 level in 1965. When the residue data for white catfish are summarized by age, there is a tendency for older fish to have higher residue levels than younger fish collected at the same time. This phenomenon may

TABLE 5

Analysis of Tissue From Collection Made in December 1960

Species	Age	Year class	Number in sample	TDE (ppm)	
				Flesh	Fat
Largemouth bass	II	1958	1	18	
	II	1958	1	13	
	II	1958	1	9	
	II	1958	1	15	
	II	1958	1	12	
	II	1958	1	4	
	II	1958	1	20	
	II	1958	1	18	359
	II	1958	9	--	28
White catfish	III	1957	1	2	
	IV	1956	1	1	
	IV	1956	1	1	
	IV	1956	1	<2	
	IV	1956	1	2	
	IV	1956	1	2	
	V	1955	1	1	
	V	1955	1	5	
	I–II	--	14	2	
	II	1958	3	1	
	IV–V	--	6	2	
	I–V	--	31	--	274
Brown bullhead	III	1957	1	5	
	III	1957	1	<1	
	IV	1956	1	<1	
	IV	1956	1	<1	
	IV	1956	1	<1	
Sacramento blackfish	II	1958	2	1	
Gull	--	--	4	--	704
Goldeneye	--	--	1	--	4
Western grebe	--	--	4	--	132

account for the apparent increase in residue levels in 1962, when only 8- and 9-year-old fish were collected. However, the data collected in 1965 from eight age groups of white catfish did not show the tendency of higher residue in older fish except for the 9- and 10-year-old fish.

Another approach to determine the trend is to examine the level of residue in a single year class sampled over a number of years. The 1958 year class of largemouth bass was sampled relatively well for the first three years and some data are available for two other years. The mean annual TDE residue in the flesh of the 1958 year class of largemouth bass decreased from 23.5 ppm in 1958 to 7 ppm in 1963 (Figure 1). The decrease in mean annual residue levels appears to follow a linear trend. The data for the other year classes are insufficient to analyze in this manner.

It appears that TDE present in the lake biota in 1965 originated from three applications for gnat control in 1949, 1954, and 1957. If there is an input of TDE into Clear Lake from converted DDT (Miskus, Blair, and Casida, 1965), the contribution from this source must be very

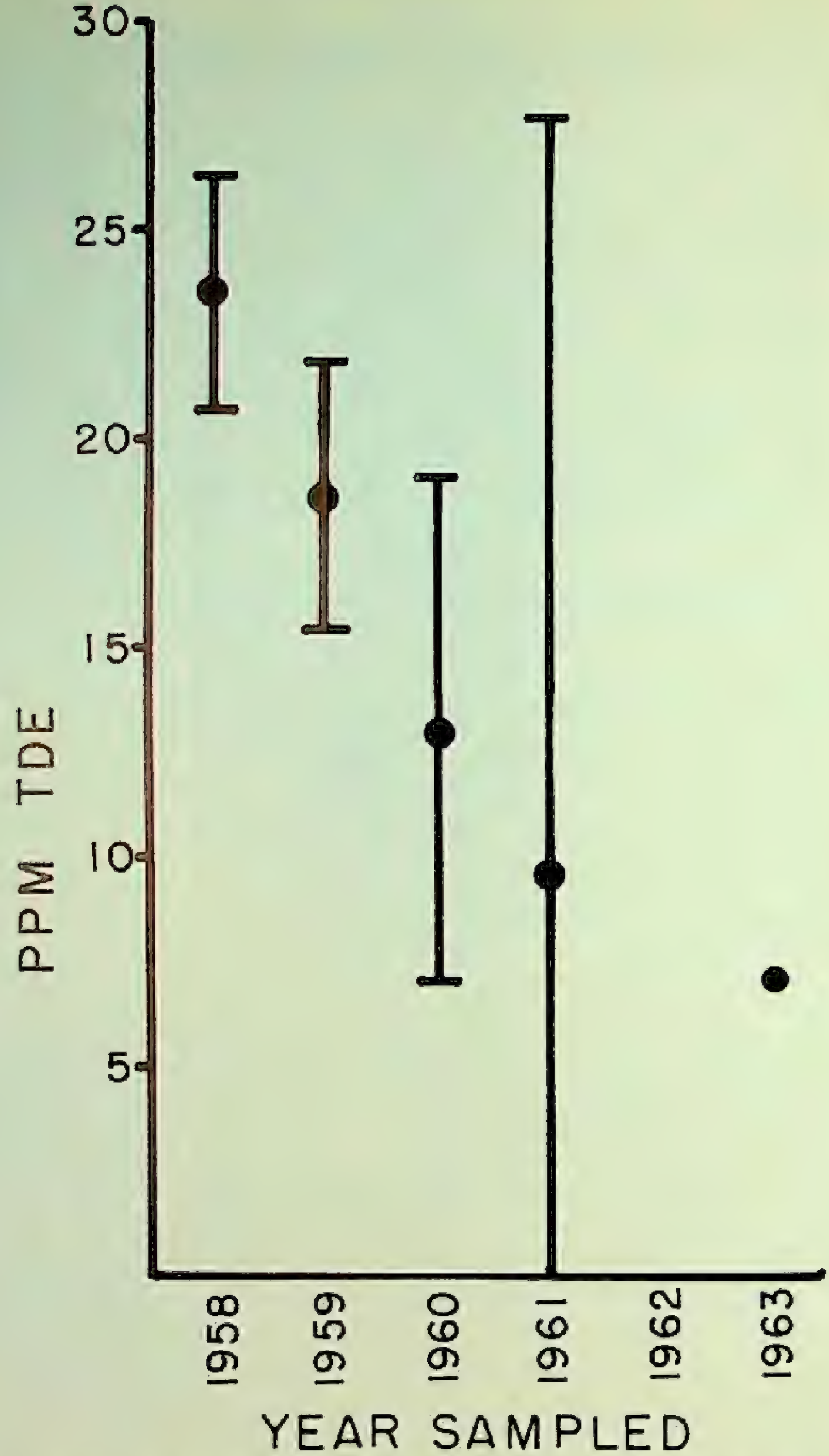

FIGURE 1—Mean TDE residues in flesh of the 1958 year class of largemouth bass in Clear Lake. The depicted ranges are ± 2 standard deviations.

TABLE 6

Analysis of Tissue From Collection Made in March 1961

Species	Age	Year class	Number in sample	Parts per million: Flesh TDE	Flesh DDE and/or TDEE	Fat TDE	Fat DDE and/or TDEE
Largemouth bass	II	1959	1	27	4		
	III	1958	1	3	<1		
	III	1958	1	16	1		
	V	1956	1	37	6		
	V	1956	1	24	4		
White catfish	I	1960	1	3	<1		
	III	1958	1	5	3		
	III	1958	1	4	3		
	III	1958	1	3	1	220	3
	VIII	1953	1	7	<1	1,435	15
	IX	1952	1	31	5	764	100
	X	1951	1	7	<1		
Brown bullhead	--	--	1	2	<1		
Gull	--	--	--	--	--	133	300
						315	402
Western grebe	--	--	1	--	--	500	574
	--	--	1	--	--	500	390
	--	--	1	--	--	276	85
	--	--	1	--	--	16	33
	--	--	1	--	--	500	248
	--	--	1	--	--	135	158

small. The amount of DDT applied under permit to farm lands in the Clear Lake basin (528 square miles) has averaged less than 1,500 lb per year since 1961 (county agricultural commissioner, pers. comm.). No information is available on sources of DDT other than agriculture, such as home gardens, household use, etc., but amounts from these sources are probably small.

All available evidence indicates that the TDE contamination of Clear Lake animals is declining. The mean annual TDE residue level in white catfish decreased from a high of 85.7 ppm in 1958 to 9.6 ppm in 1965. The mean residue level in largemouth bass decreased from 40.9 ppm in 1958 to 12.2 ppm in 1963. Residues in other animals decreased also. So long as the use of DDT or TDE in the Clear Lake basin does not increase substantially, the level of contamination should remain below the 1958 peak.

ACKNOWLEDGMENTS

The authors wish to thank Eldridge G. Hunt, Arthur I. Bischoff, and Jack L. Spruill of the Department of Fish and Game, Sherburne F. Cook, Jr., formerly of the Lake County Mosquito Abatement District,

TABLE 7

Analysis of Tissue From Collection Made in August 1961

Species	Age	Year class	Number in sample	Parts per million			
				Flesh		Fat	
				TDE	DDE and/or TDEE	TDE	DDE and/or TDEE
Largemouth bass	IV	1957	1	<0.2	<0.3		
	IV	1957	1	4.0	<0.3		
	IV	1957	1	6.1	1.7		
	IV	1957	1	0.9	<0.3		
	IV	1957	1	7.7	2.2		
	IV	1957	1	1.2	<0.3		
	IV	1957	1	8.3	2.4		
	IV	1957	1	1.8	0.6		
	IV	1957	1	11.0	3.2		
	IV	1957	5	--	--	253	82.0
	V	1956	1	1.5	0.6		
	--	--	1	3.0	0.6		
White catfish	VI	1955	1	19.1	3.9	429	113.7
	VII	1954	1	2.8	1.6	365	91.1
	VII	1954	1	23.2	4.6		
	VII	1954	1	13.6	2.6	376	91.4
	VII	1954	1	13.2	3.1	379	100.3
	VIII	1953	1	13.2	2.4	389	82.2
	IX	1952	1	38.2	5.9		
Brown bullhead	IV	1957	1	4.2	0.9		
Sacramento blackfish	--	--	1	0.5	0.8		
Gull	--	--	1	--	--	68	236.0
Western grebe	--	--	1	--	--	650	454
	--	--	1	--	--	475	383
	--	--	1	--	--	358	465
	--	--	1	--	--	633	411
	--	--	1	--	--	656	433
	--	--	1	--	--	561	350
	--	--	1	--	--	606	220

TABLE 8

Residue Levels in Samples Collected October 1962
Comparison Between Colorimetric and Gas Chromatographic Methods

Species	Age	Year class	Number in sample	Tissue	Colorimetric		Gas chromatographic		
					TDE	DDE and/or TDEE	TDE	DDE	TDEE
Largemouth bass	--	--	1	Flesh	2	1	2	1	--
White catfish	VIII	1954	1	Flesh	16	2	20	1	2
	VIII	1954	1	Flesh	30	4	36	2	3
	VIII	1954	1	Flesh	15	3	19	1	2
	IX	1953	1	Flesh	72	4	69	2	8
	VIII	1954	1	Fat	2,350	280	2,080	240	190
	VIII	1954	1	Fat	1,180	61	1,120	75	44
	VIII	1954	1	Fat	1,020	157	960	140	40
	IX	1953	1	Fat	1,550	82	1,600	75	56
Western grebe	--	--	1	Fat	1,290	800	1,040	390	320
	--	--	1	Fat	1,240	640	1,520	210	40
	--	--	1	Fat	1,180	740	1,600	170	60
	--	--	1	Fat	1,410	1,380	1,360	170	680
	--	--	1	Fat	2,500	2,360	2,240	250	560
	--	--	1	Fat	1,920	2,290	2,000	340	800
Merganser	--	--	1	Fat	58	58	62	55	40
	--	--	1	Fat	55	77	64	50	40
Ringbilled gull (*Larus delawarensis*)	--	--	1	Fat	260	177	260	190	--
	--	--	1	Fat	400	156	300	80	12
	--	--	1	Fat	195	360	150	360	28
	--	--	1	Fat	225	1,420	110	2,700	16
	--	--	1	Fat	1,020	770	570	200	320
	--	--	1	Fat	520	620	540	510	76
	--	--	1	Liver	355	810	320	400	210

TABLE 9

Analysis of Tissues From Collections Made in January, April, and June 1963

Species	Age	Year class	Number in sample	Tissue	Parts per million				Limit of detection p,p' DDT and o,p DDT
					p,p' TDE	o,p TDE	p,p' DDE	p,p' TDEE	
Largemouth bass	IV	1959	1	Flesh	13	3	2	5	0.5
	IV	1959	1	Flesh	2	--	2	2	0.5
	IV	1959	1	Flesh	11	3	1	3	0.5
	IV	1959	1	Flesh	8	2	1	2	0.5
	IV	1959	1	Flesh	9	3	1	3	0.5
	V	1958	1	Flesh	6	1	--	2	0.5
	VI	1957	1	Flesh	25	8	2	7	0.5
	--	--	1	Flesh	4	--	--	3	0.5
White catfish	--	--	1	Flesh	20	--	2	6	0.5
				Fat	350	27	26	97	10
	--	--	1	Flesh	9	--	0.5	2	0.5
				Fat	420	190	18	66	5
	--	--	1	Flesh	17	3	1	5	0.5
				Fat	1,300	160	88	190	20
	--	--	--	Flesh	33	--	4	8	0.5
	--	--	--	Flesh	12	--	1	3	0.5
	--	--	--	Flesh	10	--	1	1	0.5
Western grebe	--	--	1	Fat	220	--	93	130	10
	--	--	1	Egg from above	270	--	110	130	20
	--	--	1	Fat	800	--	230	360	20
	--	--	1	Egg from above	230	--	79	100	10
	--	--	1	Fat	1,400	120	500	1,500	20
	--	--	5	Fat	760	64	240	510	20
	--	--	3	Fat	680	--	310	750	20

TABLE 10

Analysis of Tissue From Collections Made in February and May 1965

Species	Age	Year class	Number in sample	Tissue	Parts per million p,p' TDE	o,p TDE	p,p' DDE	p,p' TDEE	p,p' DDT	Fat (%)
White catfish	III	1962	1	Flesh	2.2	0.2	0.1	0.7	<1	3.9
	III	1962	1	Flesh	7.7	0.6	0.3	2.6	<1	7.5
	III	1962	1	Flesh	6.5	--	3.0	2.1	<1	7.7
	IV	1961	1	Flesh	1.9	--	0.2	0.6	<1	3.6
	IV	1961	1	Flesh	6.6	1.2	0.3	2.6	<1	16.1
	IV	1961	1	Flesh	8.9	0.5	1.8	1.1	<1	4.7
	V	1960	1	Flesh	5.2	0.6	0.4	1.6	<1	4.3
	V	1960	1	Flesh	2.1	0.2	0.1	0.7	<1	3.6
	VI	1959	1	Flesh	8.3	0.3	0.2	2.9	<1	4.3
	VI	1959	1	Flesh	2.5	--	0.1	0.9	<1	2.5
	VI	1959	1	Flesh	8.3	0.4	0.2	2.0	<1	4.4
	VII	1958	1	Flesh	10.0	1.3	0.6	2.4	<1	6.9
	VII	1958	1	Flesh	1.3	--	0.4	0.4	<1	1.0
	VIII	1957	1	Flesh	9.8	0.5	0.3	3.3	<1	5.1
	VIII	1957	1	Flesh	18.4	1.4	1.1	3.2	<1	12.7
	VIII	1957	1	Flesh	25.1	2.0	2.5	5.6	<1	14.5
	IX	1956	1	Flesh	3.5	0.3	0.6	0.4	<1	2.8
	IX	1956	1	Flesh	30.9	4.5	1.4	7.5	<1	16.8
	IX	1956	1	Flesh	40.3	5.7	1.7	12.0	<1	24.4
	X	1955	1	Flesh	5.7	--	0.3	1.4	<1	2.0
	X	1955	1	Flesh	12.7	1.3	1.0	3.1	<1	2.3
	X	1955	1	Flesh	14.8	--	1.6	4.1	0.44*	6.6

* 2.5 ppm p, p' DDT on a fat basis (0.44 on a flesh basis). This is the only sample large enough to calculate the DDT concentration. One ppm was the limit of sensitivity on the other samples in this series.

TABLE 11

TDE Residues Found in Birds From Clear Lake

	Western grebe			Gull			Goldeneye			Merganser		
Year sampled	Number in sample	TDE ppm	Yearly mean TDE	Number in sample	TDE ppm	Yearly mean TDE	Number in sample	TDE ppm	Yearly mean TDE	Number in sample	TDE ppm	Yearly mean TDE
1959	5	1,465	1,465	12	2,134	2,134						
1960	1	825	--	3	<80	--	4	132	132			
	1	51	--	3	<80							
	1	527	--	4	701	118						
	6	1,150										
	4	132	679.3									
1961	1	500	--	1	133							
	1	500	--	1	315							
	1	276	--	1	68	172						
	1	16										
	1	500										
	1	135	321.1									
1962	1	1,300	--	1	320	--	--	--	--	1	78	
	1	1,900	--	1	370	--	--	--	--	1	80	79
	1	2,000	--	1	190							
	1	1,700	--	1	135							
	1	2,800	--	1	715							
	1	2,500	2,033.3	1	670							
	--	--	--	1	405	400						
1963	1	220										
	1	800										
	1	1,520										
	5	824										
	3	680	790.9									

TABLE 12

Mean TDE Residues Found in Largemouth Bass From Clear Lake *

Year	0	I	II	III	IV	V	VI	Not aged	Mean TDE (ppm)
1958	23.5(10)	36(2)	--	--	115(1)	--	138(1)	45.6(3)	40.0
1959	4.4(15)	18.6(25)	--	--	31(1)	--	--	--	13.7
1960	--	--	13.0(32)	9(1)	21(1)	111(1)	6(1)	--	15.6
1961	--	--	27(1)	9.5(2)	4.9(9)	20.8(3)	--	3.0(1)	9.7
1962	--	--	--	--	--	--	--	3.0(1)	3.0
1963	--	--	--	--	10.8(5)	7(1)	33(1)	4.0(1)	12.2

* Number in sample is listed in parentheses.

TABLE 13

Mean TDE Residues Found in White Catfish from Clear Lake *

Year	Not aged	I	II	III	IV	V	VI	VII	VIII	IX	X	Mean TDE (ppm)
1958	77.4(67)	--	22(1)	26(1)	--	133.6(6)	--	--	146(3)	168(2)	133.0(1)	85.7
1959	--	9.4(3)	14.0(5)	24.8(3)	35.8(10)	44.4(9)	34.9(4)	77(2)	--	184(1)	--	36.2
1960	2(20)	--	1.4(4)	3.5(2)	3.6(8)	9.7(7)	5(1)	47.0(1)	30(4)	21.3(4)	40.8(4)	10.5
1961	--	3(1)	--	4.0(3)	--	--	19.1(1)	13.2(4)	10.1(2)	31.6(2)	7(1)	13.1
1962	--	--	--	--	--	--	--	--	31.3(3)	86(1)	--	44.0
1963	17.3(6)	--	--	--	--	--	--	--	--	--	--	17.3
1964												--
1965	--	--	--	5.0(3)	6.4(3)	4.0(2)	6.5(3)	6.5(2)	5.3(3)	25.5(3)	11.4(3)	9.6

* Number in sample is listed in parentheses.

and Frank Grasteit, who fishes commercially at Clear Lake, for their various roles in collecting the samples.

We also wish to thank the following chemists of the State Food and Drug Laboratory who performed the analyses: James J. Chan, James I. Ferguson, Roland Gee, Thomas E. Hillis, Herbert T. LeFavoure, Conrad Peterson, Ray Okamura, and Glenn Smith.

REFERENCES

Andrews, R. D., III. 1963. Preparation of catfish spines for sectioning. Prog. Fish-Cult., 25 (4) :220–221.

Hunt, Eldridge G., and Arthur I. Bischoff. 1960. Inimical effects on wildlife of periodic DDD applications to Clear Lake, Calif. Fish and Game, 46 (1) :91–105.

Miskus, Raymond P., Deanna P. Blair, and John E. Casida. 1965. Conversion of DDT to DDD by bovine rumen fluid, lake water and reduced porphyrins. Agric. and Food Chemistry, 13 (5) :481–483.

Schechter, Milton S., Milton A. Pogorelskin, and H. L. Haller. 1947. Colorimetric determination of DDT in milk and fatty materials. Ind. and Eng. Chemistry, 19 :51–53.

Stanley, Ronald L., and Herbert T. LeFavoure. 1965. Rapid digestion and cleanup of animal tissues for pesticide residue analysis. Jour. Assoc. Official Agric. Chemists, 48 :666–667.

Calif. Fish and Game, 55 (3) : 179–196. 1969

THE INFLUENCE OF SOIL TEXTURE ON THE STRUCTURE, DURABILITY, AND OCCUPANCY OF MUSKRAT BURROWS IN FARM PONDS[1]

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Muskrats *(Ondatra zibethica)* living in ponds on a farm in Siskiyou County, California, constructed several types of burrow systems. (i) Breeding burrows are extensive and relatively permanent systems constructed in soils high in clay and low in sand. They are occupied by large strong animals, mostly adults and presumably dominants in the population. (ii) Winter burrows are small temporary structures, situated in sandy soils and occupied by small individuals, presumably young. These burrows are built in autumn and collapse in spring. (iii) Feeding burrows are shelters constructed near food supplies and are used only for feeding.

Continuity of the population relates to the welfare of the adults snugly situated in the breeding burrows. It is postulated that damage might be controlled if the dam and other burrow sites were covered with a ft or more of sand, which would preclude effective construction of breeding burrows.

INTRODUCTION

The many farm ponds, reservoirs, canals, and irrigation ditches in central and northern California provide the introduced muskrat (*Ondatra zibethica*) with an ideal habitat. Unfortunately, the muskrat's habit of burrowing into dams, levees, and embankments has caused great economic loss to the agricultural industry in California. The purpose of this investigation was to analyze the habitat requirements of the muskrat and to suggest management techniques by which agriculturists might reduce this economic loss.

STUDY AREA

This study was conducted on the Shasta View Ranch, a cattle ranch 1 mile north of Montague, Siskiyou County, California, elevation 2,600 ft (Figure 1). Supplementary observations were made on the Prather Ranch, 1 mile south of Montague; on the Heide Ranch, 6 miles west of Fort Jones, Siskiyou County; on the Earhart Ranch, 3 miles south of Wheatland, Sutter County; and on the Haskell Ranch, 10 miles south of Marysville, Yuba County.

There are three reservoirs and several hundred yards of irrigation ditches on the Shasta View Ranch which serve as muskrat habitat. The reservoirs are 2.5, 4.5, and 0.9 acres in size and are retained by earthen dams approximately 60 ft thick at the base, 25 ft thick at water level, 10 ft thick at the top, and 12 ft high. In addition, the ranch is bordered by a slough which passes near other reservoirs on adjacent ranches and hence serves as a route of travel for dispersing muskrats.

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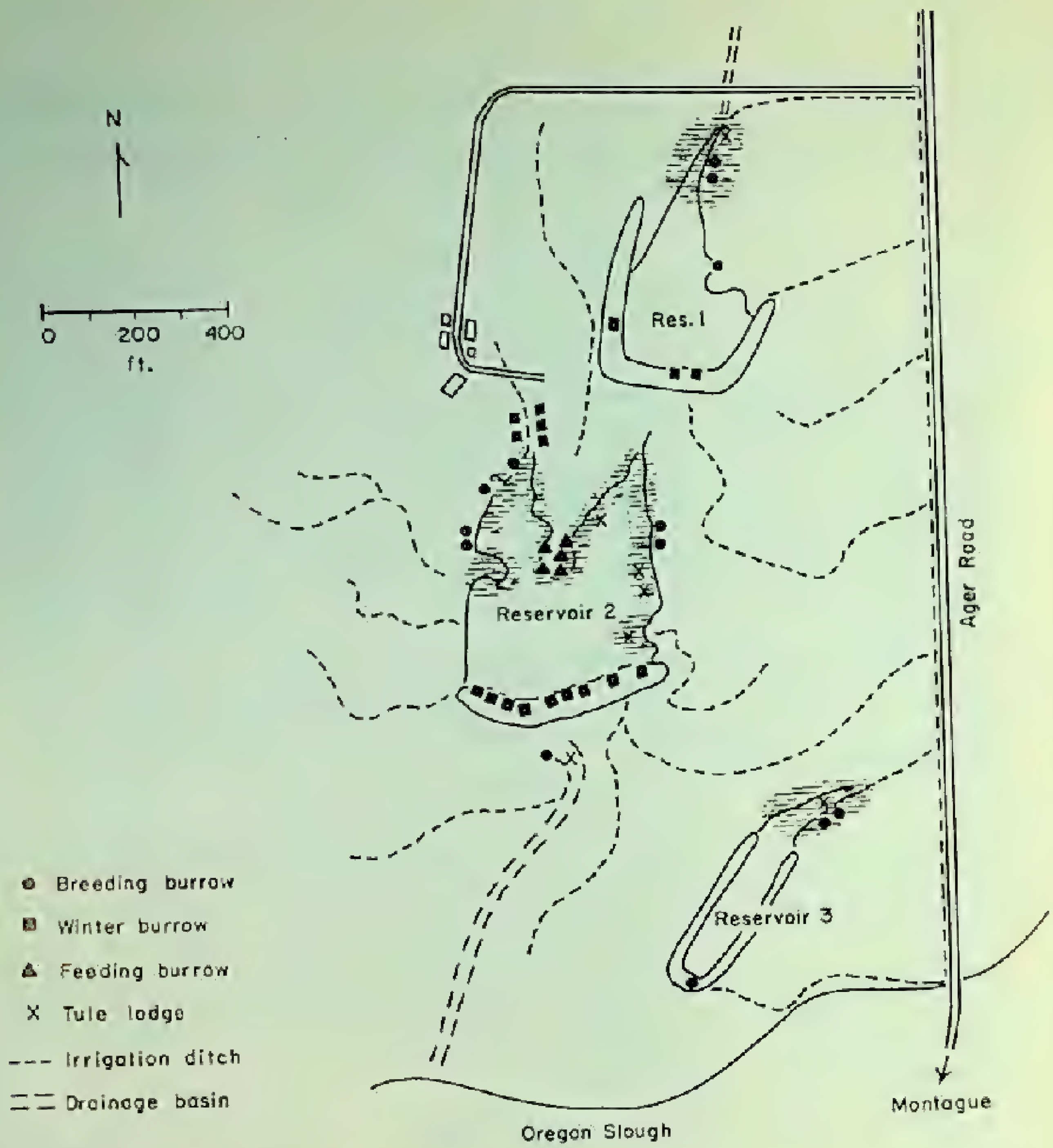

FIGURE 1—Principal muskrat habitat on the Shasta View Ranch, Siskiyou County.

The dominant plants of the reservoirs are bulrushes (*Scirpus* spp.) and cattails (*Typha latifolia*). Thick stands of both species occur at the shallow ends of all three reservoirs.

Most of the soil on the Shasta View Ranch is Montague clay loam adobe, occupying low, gently sloping alluvial fans and foot slopes (Watson, Wank, and Smith, 1923); Reservoir No. 2 was constructed of this soil. Reservoir No. 1 is located on Agate gravelly loam, a granular soil low in organic matter. Oregon Slough and Reservoir No. 3 are located on Hovey loam, a friable gray soil with a high percentage of lime.

The average monthly temperature at a climatological station near Shasta View Ranch varies from 33.8 F (January) to 72.2 F (July),

with a yearly average of 52.0 F. Temperature fluctuations are wide, both on an annual and daily basis; on the average, there are 132 days per year with a minimum of 32 F or less and 55 days per year with a maximum temperature of 90 F or above. The annual precipitation averages 17.8 inches, 61% of which falls during November through February. Snowfall averages 20.7 inches per year, with 49% falling in January.

TYPES OF BURROWS

The muskrat burrows observed in this study ordinarily consisted of a tunnel leading upward from an underwater entrance to one or more chambers in the embankment above the water level. Three relatively distinct types of burrows were recognized: (i) extensive systems of tunnels and chambers, which were designated breeding burrows; (ii) small systems, usually with one chamber, one tunnel, and one entrance, designated winter burrows; and (iii) small systems with one or two entrances, one chamber, and no tunnels, designated feeding burrows. Table 1 summarizes characteristics of these three types of burrows.

TABLE 1

Characteristics of Muskrat Burrows Observed on the Shasta View, Prather, Heide, and Earhart Ranches

	Breeding burrows		Winter burrows		Feeding burrows	
	N = 15		N = 21		N = 5	
	$\overline{X}$	Range	$\overline{X}$	Range	$\overline{X}$	Range
Number of entrances	4.6	2 to 8	1.5	1 to 2	1.4	1 to 2
Depth of entrances (inches)	−3*	−23 to 0	−5	−25 to +3	−1	−2 to +2
Number of chambers	3.7	2 to 6	1.2	1 to 2	1	1
Chamber roof thickness (inches)	8	3 to 30	18	3 to 60	2	1 to 3
Distance into embankment (inches)	79	42 to 216	42	0 to 156	26	12 to 46
Distance up embankment (inches)	19	11 to 36	16	6 to 26	5	3 to 7
Displacement of embankment (ft³)	3.28	1.16 to 5.08	1.32	0.21 to 2.15	0.39	0.23 to 0.61
Slope (deg)	39	11 to 80	47	14 to 80	31	15 to 45
Duration of burrows (months)	19.4	12 to 22	6.8	3 to 22	3.6	2 to 6
Distance to next burrow (ft)	13	3 to 50	20	2 to 60	4	3 to 10

* A negative value indicates that the top of the burrow was below water level.

Breeding burrows (Figure 2) appeared to function as living and nesting areas throughout the year. Such systems were composed of numerous entrances leading into a complex network of tunnels and chambers. They extended farther into the embankment and rose higher above the water than did either of the other two types. Due to the large number of chambers and tunnels, displacement of soil from the embankment was greater in breeding burrows than in other burrows. These large burrows were ordinarily constructed in clay soil or in heavy sod on the feathered edges of the reservoirs. Once constructed, such systems rarely collapsed or were otherwise destroyed.

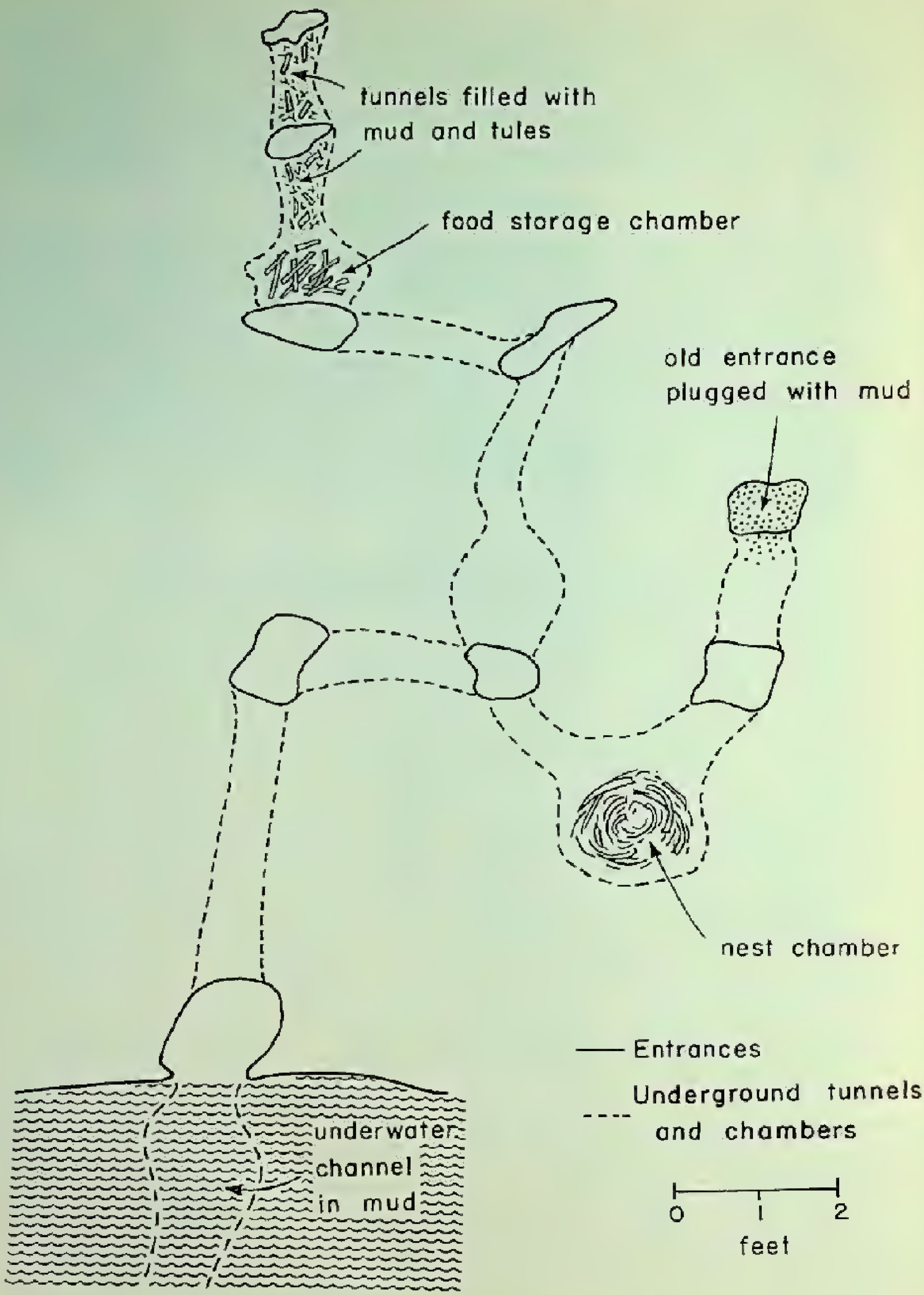

FIGURE 2—Top view of a typical breeding burrow.

Winter burrows (Figure 3A) resembled breeding burrows except that they were smaller and less complex. They usually had only one chamber and one or two entrance tunnels. These systems were constructed primarily in September and October and served as living areas during the winter months. The most common form consisted of an underwater entrance leading into a small chamber by way of a relatively long tunnel; an additional entrance and tunnel above the water level was present in 53% of the winter burrows examined. Such systems extended into the embankment only about half as far as did breeding burrows. These systems were usually found on tall, steep embankments; consequently, the roof thickness was greater than in the other types of burrows. Winter burrows were commonly built in relatively sandy soil. Unlike the more permanent breeding burrows, these systems were transitory, ordinarily remaining intact for 6 months or less. Once such a burrow collapsed, it was never repaired or rebuilt.

All of the feeding burrows (Figure 3B) in the study area were located on one peninsula in Reservoir No. 2, immediately adjacent to a large stand of cattails and bulrushes. These burrows appeared to serve as refuges while the muskrats were feeding on the nearby vegetation.

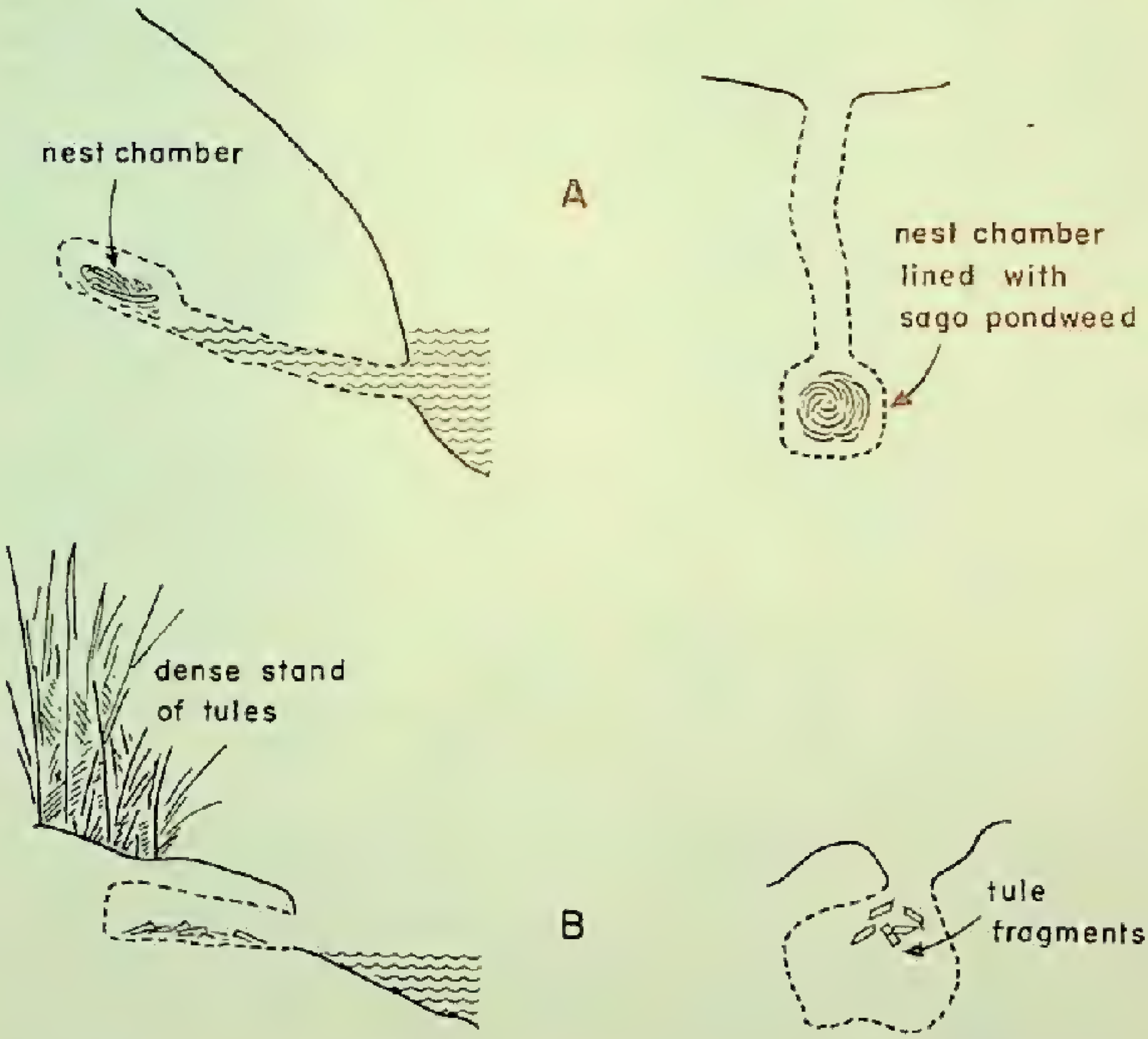

FIGURE 3—Side and top views of A, typical winter burrow, and B, typical feeding burrow.

They consisted of one or two entrances approximately at water level leading into a single chamber. No tunnels were present; the entrances opened directly into the chamber. Feeding burrows extended into the embankment only the length of the chamber and rose in the embankment just slightly above water level, making them subject to flooding. Due perhaps to the thin chamber roof (1 to 3 inches), the low percentage of clay and high percentage of sand at such sites, and the frequent flooding, these burrows were very shortlived. However, unlike the winter burrows, a collapsed feeding burrow was often rebuilt.

The tunnels found in breeding burrows and winter burrows were 4 to 6 inches in diameter and extended up to 65 inches in length between chambers and entrances. The chambers in all three types of systems varied greatly in size and shape, ranging from slight expansions of the tunnel to the largest found, 37 x 12 x 8 inches. Neither tunnels nor chambers were ever smaller than 4 inches in any direction. The walls of both were often lined with claw marks but with few or no incisor impressions, indicating that the feet were probably the most important digging tools.

Total displacement of soil from the embankment was determined by calculating the volume of all the tunnels and chambers in each system (Table 1). The average displacement of breeding burrows was 2.5 times the average displacement of winter burrows and 8.4 times the average displacement of feeding burrows.

The floor of at least one large chamber in both breeding burrows and winter burrows was ordinarily thickly lined with sago pondweed (*Potamogeton pectinatus*), a common plant in all of the reservoirs in the study area. Additional chambers in the breeding burrows were tightly packed with short stems of cattails and bulrushes and apparently served as food storage chambers; no such food stores were ever found in winter burrows. Fragments of vegetative stems were commonly seen in feeding burrows, where individuals had apparently dropped them while feeding.

Feces were never found in any chamber or tunnel, but were deposited in discrete piles on rocks, logs, or raised areas of sod a short distance from the burrows. In general, the burrows were kept clean of rotting or decaying material; little except relatively green vegetation was found in the systems.

Dense vegetative cover near the entrance of the burrow appeared unnecessary. All of the breeding burrows and winter burrows were constructed in areas free from any vegetation except short, sparse grass. Most of the feeding burrows were surrounded by stands of cattails or bulrushes, but none was completely concealed.

Beshears and Haugen (1953*a*) described the dimensions of muskrat burrows in farm ponds in Alabama. They did not differentiate between burrow types but reported their findings as averages of all burrows examined. Their results generally correspond to observations in this study. The Alabama muskrats built one to six chambers with one to nine entrances; the size of the chambers varied from 6 x 4 inches to 10 x 10 inches. The systems penetrated 48 to 60 inches into the banks and rose vertically 6 to 50 inches.

Grinnell, Dixon, and Linsdale (1937) described the same three burrow types in a population of the Colorado River muskrat in the Imperial Valley of California, but gave no information on the dimensions, functions, or relative abundance of the various systems.

LODGES

Seven lodges fashioned from plant materials were built during the 22-month study, five in the winter of 1965–66 and two in the winter of 1966–67. None remained intact and active longer than 6 months; the average duration was 4.4 months. These lodges were built at approximately the same time as the winter burrows and like the burrows were washed away in the high water of early spring.

Five of the lodges were dismantled and examined after they became inactive and began to collapse. They ordinarily had at least one entrance

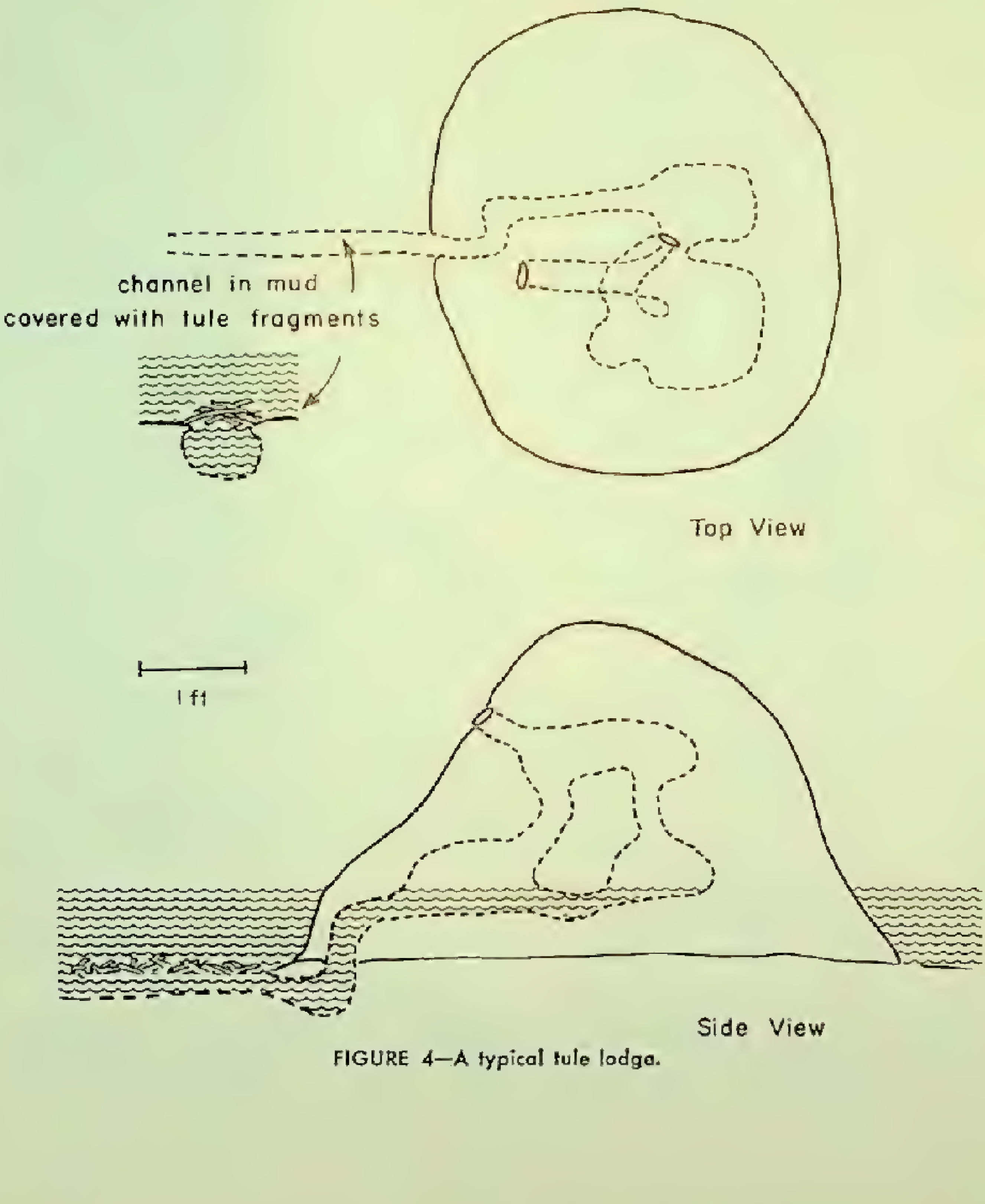

FIGURE 4—A typical tule lodge.

under water and one entrance above water; there were two or three large chambers in the center of the lodge (Figure 4). All of the lodges were built on a shallow edge of the reservoir where the water was never more than 12 inches deep. Six of the houses were constructed of cuttings of bulrushes and cattails, the seventh almost entirely of small balls of sago pondweed.

The feet, bills, and wings of blackbirds (*Agelaius* sp.) and coots (*Fulica americana*) were found in the main chambers of two of the lodges; a dead muskrat was found in a third lodge. All of these lodges had a small hole near the top, typical of the openings made by mink when raiding lodges. Apparently a mink was using the inactive lodges to feed on dead birds. An adult female mink was caught in a muskrat trap in Reservoir No. 2 a short time later; no further mink sign was noted during the study.

A fourth lodge had the nest of a Canada goose (*Branta canadensis*) on the top during the spring of 1966.

Other workers have described two basic types of muskrat lodges found in muskrat marshes: (i) large dwellings, which usually protrude 3 to 5 ft above the water level and (ii) feeding houses, smaller tule structures extending less than 2 ft above the water (Seton, 1929; Sather, 1958). The tule lodges in this study were dwellings; no feeding houses were observed.

DURATION OF BURROWS AND LODGES

The time of construction and duration of the three types of burrows and tule lodges found on the Shasta View Ranch are shown in Figure 5.

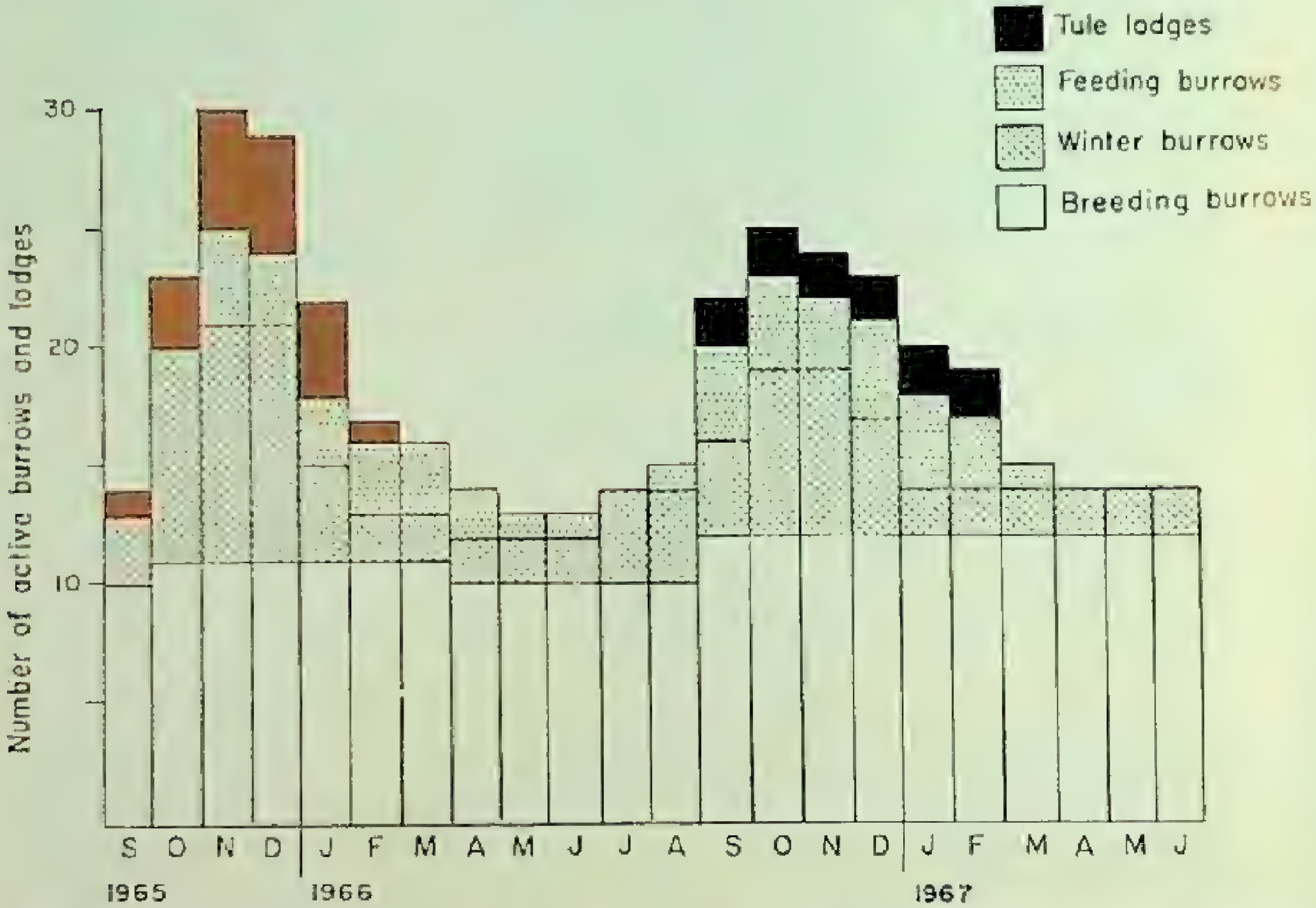

FIGURE 5—Seasonal variation in the number of burrows and lodges present on the Shasta View Ranch.

The winter burrows, feeding burrows, and tule lodges were constructed in late fall. They remained intact and active during the winter months when the ground was frozen and frequently covered with snow. Most of these systems collapsed in early spring after heavy rains thawed the soil.

The duration of breeding burrows was much longer; 93% of the burrows on the Shasta View Ranch remained intact and occupied the entire 22 months of the study. Very few new breeding burrows were constructed during this period.

No other studies were found which recorded the time of construction or duration of muskrat burrows in soil embankments. However, as in this study, Johnson (1925) and Sather (1958) observed that muskrats began building new tule lodges in July and August, with a peak of building activity in October or November; the lodges began to collapse in early spring. Nicholson and Davis (1957) recorded the number of new tule lodges built per month on Blackwater Refuge in Maryland. They found that lodge construction reached a peak in February; the life expectancy of the lodges averaged 5.14 months.

INFLUENCE OF SOIL AND SLOPE

Mechanical analyses were performed of soil samples taken from individual burrow sites to determine the relationship of soil texture to longevity of muskrat burrows.

Soil samples were collected at the entrance of each burrow and air-dried. The soil aggregates were broken apart with a mortar and pestle and the gravel and rocks removed with a 2-mm sieve. A portion of the air-dry soil was weighed, dried in an oven at 110 C for twelve hr, and then reweighed. The air-dry moisture content was calculated.

The particle size distribution of the soil samples was determined by the hydrometer method, a technique by which the concentration of suspended solids is measured at various time intervals after the soil has been thoroughly dispersed in a sedimentation chamber. The soil suspension was prepared from the equivalent of 50.0 g of oven-dry soil mixed with 2 g of Calgon and diluted with distilled water to make 1 liter. Hydrometer readings were taken at 30 sec, 45 sec, 6 hr, and 24 hr. For details of the method, see Kilmer and Alexander (1949), Day (1950), and Black (1965).

Burrows were classified into two groups: (i) permanent burrows, which were systems that remained intact for at least 12 months, and (ii) temporary burrows, which were systems that collapsed in less than 1 year. Permanent burrows include all of the breeding burrows and two of the winter burrows investigated in this study; temporary burrows include all of the feeding burrows and the remainder of the winter burrows.

A wide range of soil types was found in the substrate of the dams. Sand content varied from 16.0 to 81.0%, clay content varied from 6.5 to 39.0%, and silt content varied from 9.0 to 46.5%.

Figure 6 indicates that permanent burrows were constructed in soil containing a higher percentage of clay and a lower percentage of sand than the soil where temporary burrows were constructed. Silt content was not significantly different. Soils composed of 16 to 43% sand con-

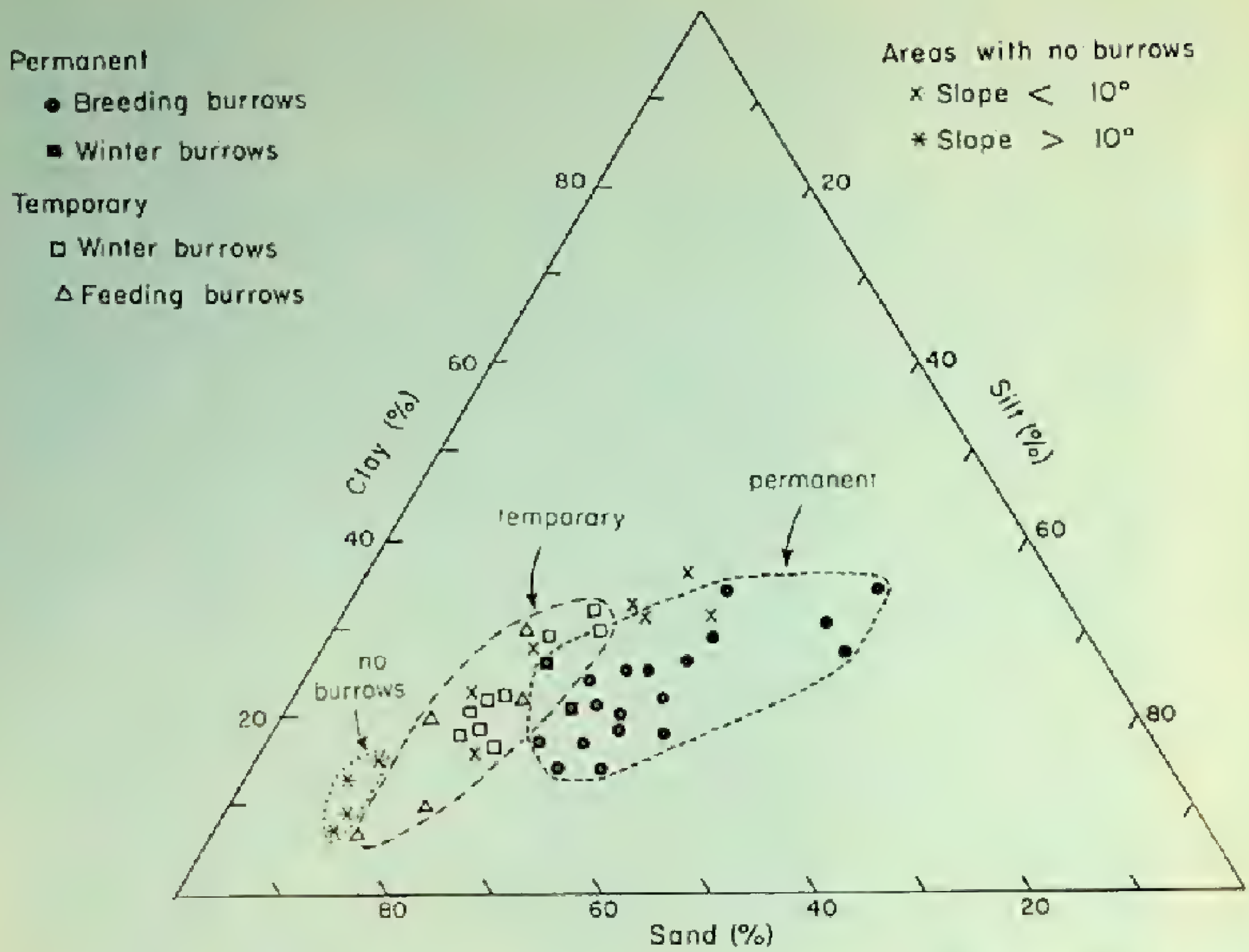

FIGURE 6—Textural classification of soils taken from burrow sites on the Shasta View Ranch.

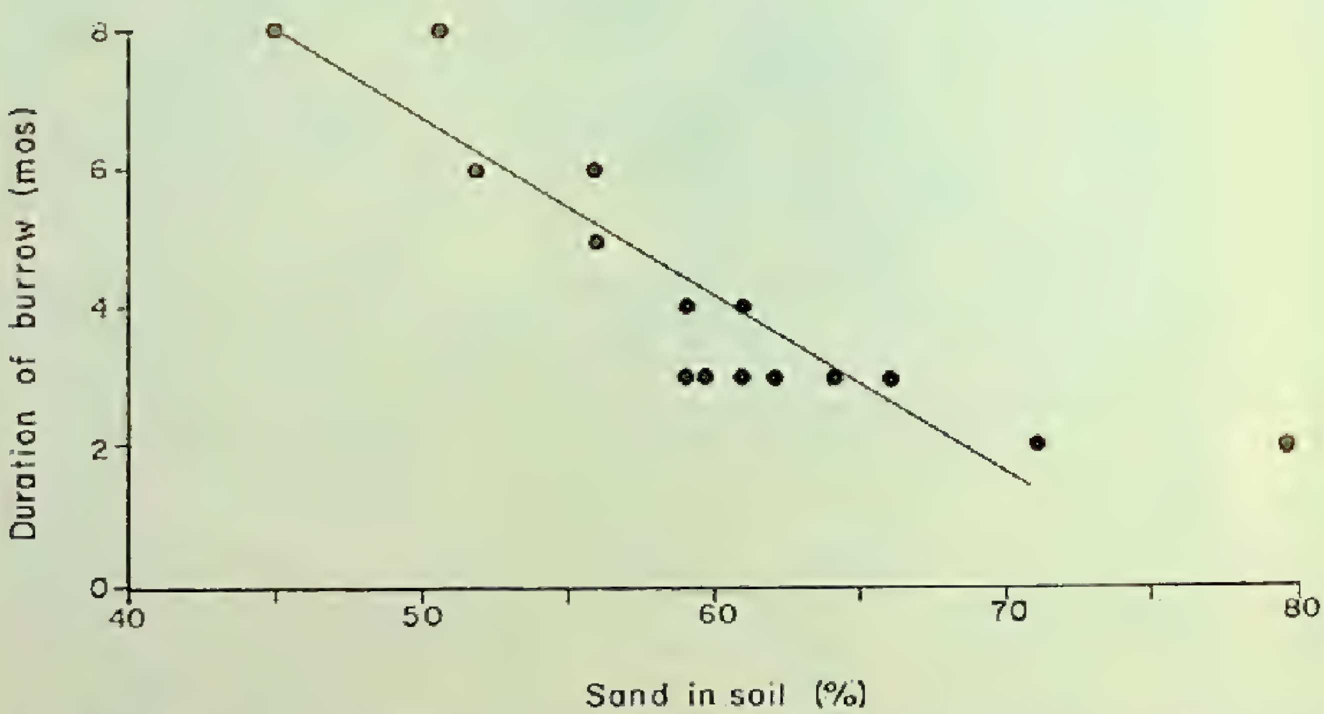

FIGURE 7—Inverse relationship of the percentage of sand in soil and the duration of individual temporary burrows. The line was determined by the least squares method.

tained only permanent burrows, and soils composed of 58 to 80% sand contained only temporary burrows.

The amount of sand in the soil was inversely related to the longevity of the temporary burrows. Figure 7 indicates that a burrow is more likely to collapse after a short period of time if there is a high percentage of sand in the soil at that location. The percentage of sand in the soil and the longevity of temporary burrows show a correlation coefficient of —0.77 with a 99% significance probability.

Mechanical analyses were performed of soils taken from areas where no burrows could be found for at least 25 ft on either side. Soils taken from areas with no burrows but with a slope of 10° or more contained at least 73% sand; soils taken from areas lacking burrows but with a slope less than 10° contained 34 to 64% sand (Figure 6). In the former case muskrat burrowing activity was limited by the excessive amount of sand in the soil, even though a steep embankment was present. In the latter case soil texture was adequate for the construction of either permanent or temporary burrows but the nearly level slope apparently prevented burrowing activity.

Thus, both soil texture and slope influence the site preference and permanence of individual burrows. Muskrats appear to require a slope of at least 10° in order to construct a burrow of any type, no matter how little sand is present. The muskrats were able to construct permanent burrows so long as the slope of the embankment was above 10° and the percentage of sand present in the soil was less than 45%. A sand content of 58 to 70% and a slope greater than 10° allowed the construction of only temporary burrows, lasting 2 to 6 months. Embankments composed of soil of more than 70% sand contained temporary burrows or no burrows at all, no matter how steep the slope.

TEMPERATURE

Temperature measurements were taken every 3 hr inside the individual burrow systems described in Figure 8 on December 28–29, 1966. The permanent burrow constructed in sod remained at a higher temperature and allowed much less fluctuation in temperature than did any of the other types of burrows. The temporary burrow constructed in sandy soil had the lowest average temperature and allowed the most temperature fluctuation of any of the burrows. The other temporary burrow insulated with sago pondweed had a higher average temperature and lower degree of temperature fluctuation than the uninsulated temporary burrow. The average temperature of the permanent burrow constructed in bare clay was intermediate between that of the insulated and uninsulated temporary burrows.

These results are in accord with the findings of researchers in soil physics. Kersten (1949) reported that the thermal conductivity of different soils followed the order of sand>loam>clay, indicating that frost penetration would be faster in sand than in clay. In addition, Baver (1956) has stated that frost penetration is more rapid when the soil is bare than when it has a grass cover. Thus, cover tends to lessen the temperature fluctuations of the subsoil.

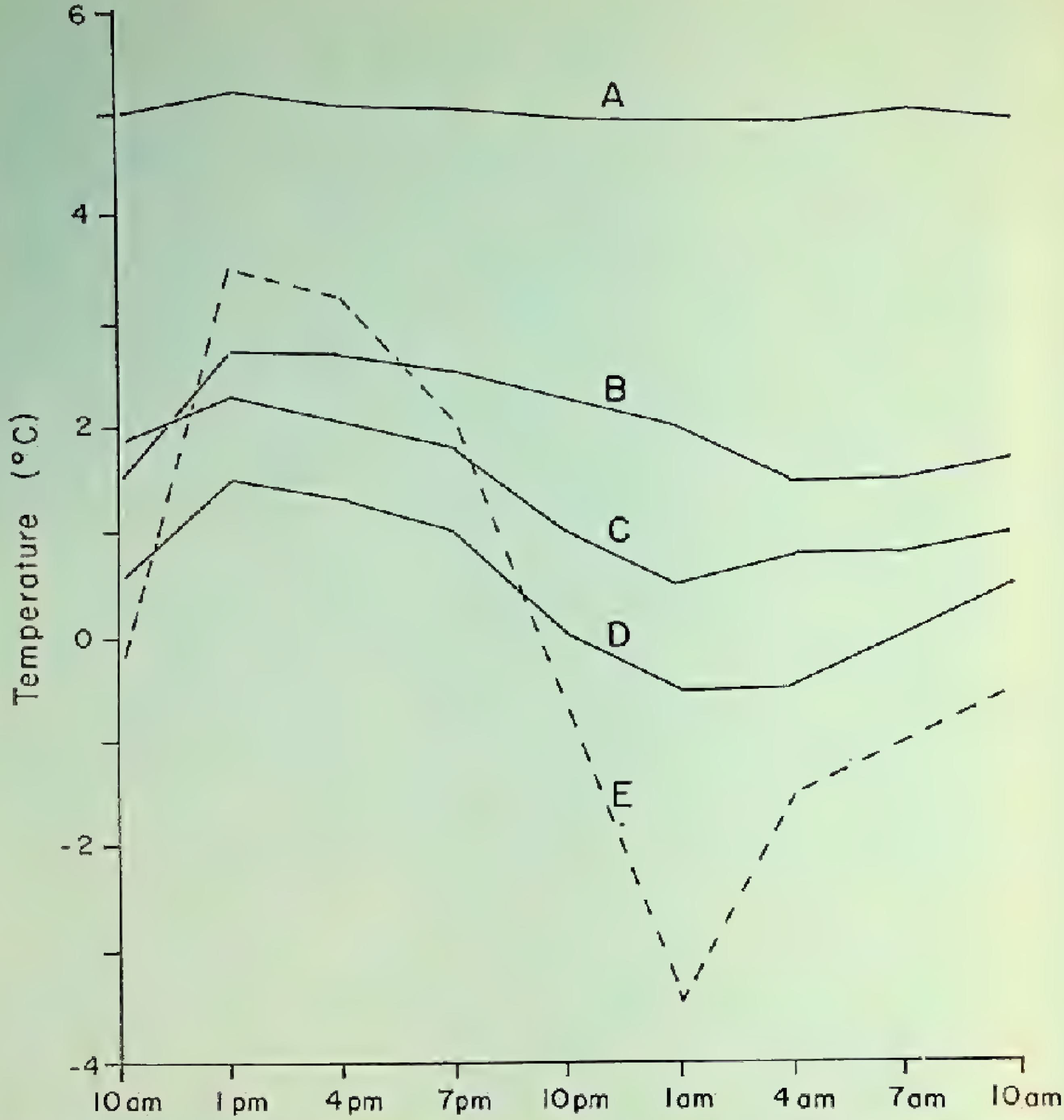

FIGURE 8—Temperature fluctuation inside the main chamber of the following individual muskrat burrows on December 28–29, 1966: A, a permanent breeding burrow constructed in sod; B, a temporary winter burrow in sand in which a muskrat had lined all the walls and chambers and blocked all the entrances with sago pondweed; C, a permanent breeding burrow constructed in clay with no vegetative cover, and D, a temporary winter burrow in sand. E represents the air temperature 12 inches above the surface of the soil. The chamber roof was 2 ft away from the water in all cases.

THE SPACING AND OCCUPANCY OF BURROWS

The muskrat burrows on the Shasta View Ranch were not evenly spaced around the shoreline of the reservoir but occurred in groups. Ten of the twelve breeding burrows occurred as closely adjacent pairs. Such systems were ordinarily found as close as 2 to 3 ft apart but each group was separated by up to 50 to 60 ft of potential burrowing sites. The winter burrows were more widely spaced but still tended to be grouped in pairs or triplets.

In order to determine whether there were differences in size, age, or sex among the individuals occupying the different burrow types, muskrats were trapped in both permanent breeding burrows and temporary winter burrows during the winter of 1966–67. Traps were set inside burrows or within 1 ft of the entrance to insure that the muskrat caught was an occupant of that burrow. The animals were divided into two age groups, adults and subadults, on the basis of the degree of root development and fluting of the first upper molar (Olsen, 1959).

No burrow was unoccupied for more than 24 to 48 hr, even with daily intensive trapping. As soon as the occupant of a burrow was removed, a new individual apparently moved into the system.

The occupants of the permanent breeding burrows were substantially larger, as indicated by body weight and overall body length, than the occupants of temporary winter burrows (Figure 9). Muskrats trapped in breeding burrows weighed from 1,021 to 1,342 g, averaging 1,235 ± 22 g; these individuals varied from 578 to 616 mm in total body length, averaging 604 ± 2 mm. Muskrats taken from winter burrows weighed from 598 to 1,065 g with an average of 896 ± 23 g; they measured from 411 to 598 mm, averaging 520 ± 12 mm.

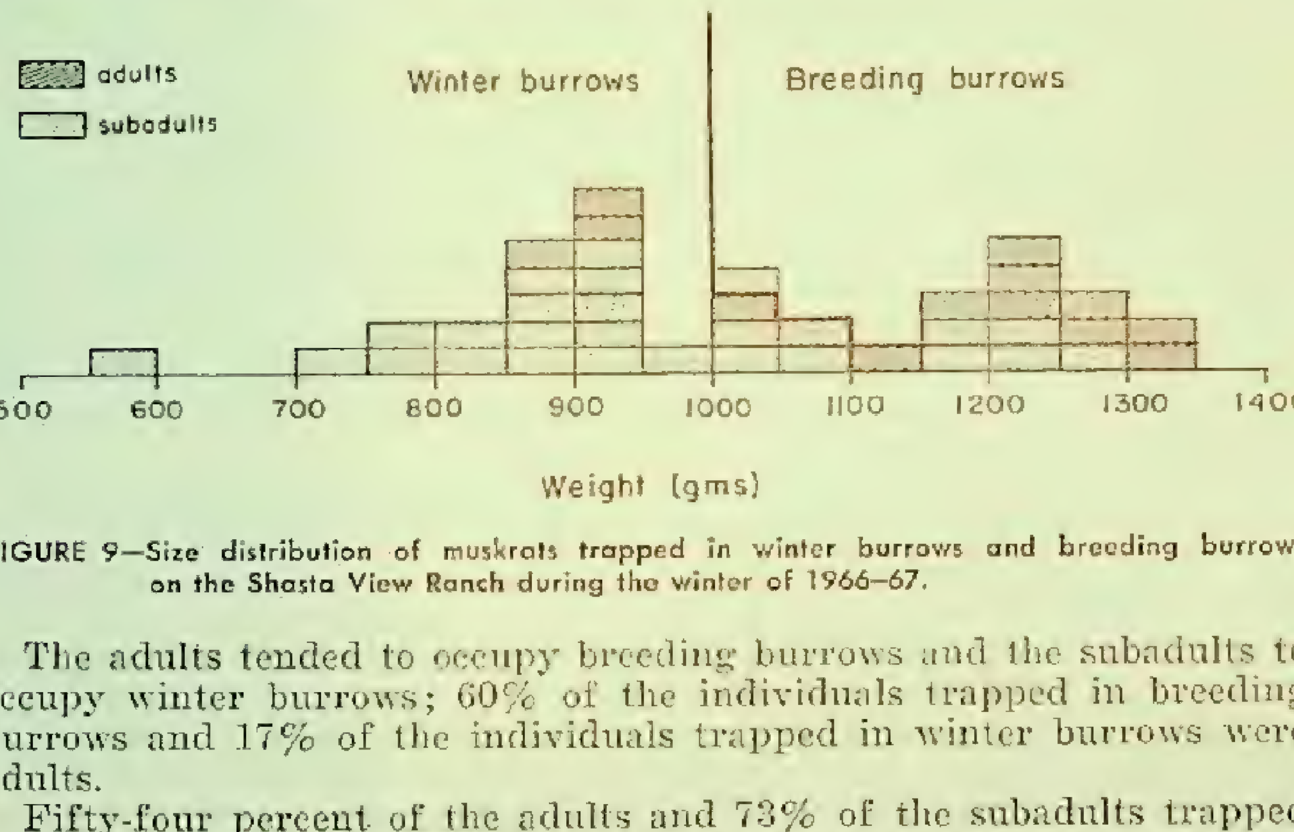

FIGURE 9—Size distribution of muskrats trapped in winter burrows and breeding burrows on the Shasta View Ranch during the winter of 1966–67.

The adults tended to occupy breeding burrows and the subadults to occupy winter burrows; 60% of the individuals trapped in breeding burrows and 17% of the individuals trapped in winter burrows were adults.

Fifty-four percent of the adults and 73% of the subadults trapped were males. Errington (1963) consistently found smaller proportions of males among the adults as compared with the young and attributed this difference to the greater conspicuousness and vulnerability of surplus, transient adults during the breeding months.

An apparent pattern of spacing between the sexes was observed. The trapping data suggest that the pairs of breeding burrows were occupied by a male in one system and a female in the closely adjacent system. When an individual of one sex was trapped and removed, an individual of the same sex generally moved into the vacant burrow. Both the male and female were removed at the same time from one pair of dens; the

burrows were immediately reinvaded by another pair, but the male occupied the former female burrow and the female occupied the former male burrow. In nine cases out of nine a male and female were observed to be living in adjoining breeding burrows.

The sets of winter burrows also tended to be occupied by a male in one system and a female in the adjoining system (seven times out of eight); three male subadults living in close proximity constituted the exception.

COMPETITION FOR BURROWS

The preceding data on duration of burrows, soil texture, slope, and temperature indicate that the permanent breeding burrows provided a better habitat for muskrats than the temporary winter burrows. The breeding burrows remained intact for a much longer period of time, due to the higher percentage of clay and lower percentage of sand in the soil at such sites; these excavations could be larger with more chambers and escape exits due to their structural strength. The average temperature was higher in winter and temperature fluctuations were smaller in the well-insulated breeding burrows. All such physical properties seem to indicate that temporary winter burrows provide mediocre or substandard living accommodations and permanent breeding burrows provide prime habitat.

However, since there were many more muskrats living in the area than there were permanent burrows to accommodate them, territorial interactions between occupants of these burrows and peripheral individuals were inevitable. The trapping data indicate that the largest individuals were most likely to be the victors in such interactions and could therefore occupy burrows in prime habitat; i.e., breeding burrows. Overall body size seemed to be more important than age in such interactions, since the smallest adults in the population were relegated to temporary winter burrows, while larger subadults occupied permanent breeding burrows (Figure 9).

Although fights between muskrats were witnessed only three times in this study, evidence of fighting in the vicinity of the burrows was found often. Soil and snow were thrown in every direction, imprints of a struggle were obvious in the mud and snow, and splattered blood was found occasionally. When the pelts of trapped muskrats were examined closely, the smaller individuals that had been occupying temporary winter burrows invariably had numerous scars or open cuts on their bodies, particularly in the dorsal regions. Most of these smaller individuals had broken or damaged tails. On the other hand, the largest individuals trapped in permanent breeding burrows had pelts in excellent condition and only occasionally bore fresh scars and cuts. There did not appear to be a difference in the degree of scarring between the sexes.

In light of the strong competition for burrows, it cannot be determined from this study whether the individuals trapped in any of the burrows were the original builders of the system or the winners of a territorial encounter. However, it is hypothesized that the large numbers of temporary burrows constructed in the fall were built by subadults. The sharp increase in new winter burrows coincided both years with the annual fall dispersal, during which muskrats could be observed

moving between the ponds, ditches, and slough. Live-trapping studies in other areas have indicated that these transient individuals participating in the annual fall dispersal are primarily subadults (Errington, 1963). In addition, behavioral and physiological studies have shown a short period of increased fighting and territoriality, with an accompanying increase in adrenal and pituitary sizes, during these fall months, particularly among the adults (Beer and Meyer, 1951). Apparently the wandering subadults have been excluded from the parental burrows during this period of increased territoriality and are in search of a site for a winter home and territory. A similar phenomenon has been observed in another fossorial rodent, the pocket gopher (*Thomomys bottae*). A seasonal peak in new burrow workings typically coincides with the dispersal of young gophers from the parental burrows at the end of the breeding season (Miller and Bond, 1960; Miller, 1964).

It is not known why the young muskrats chose sandy soil for construction of their new winter burrows. Due to their inexperience they may simply have chosen the area where digging was the easiest; i.e., in sand. They may have been incapable of digging in compact clay until they were of fully adult size, as has been shown with moles (Godfrey and Crowcroft, 1960). Or, the already established adults may have defended territories large enough to encompass all prime burrowing sites, leaving only substandard areas for the subadults.

CONTROL OF MUSKRAT DAMAGE IN FARM PONDS

Several techniques have been suggested for controlling muskrat damage in farm ponds; e.g., steel-trapping, riprapping the dam with rocks, metal, or poultry wire, injecting repellents such as calcium carbide or naphthalene flakes into holes in the dam, filling in the burrows with coarse gravel, clearing dense vegetation, etc. (Nagel, 1945; Beshears and Haugen, 1953*a*, 1953*b*; Wilson, 1960). All such methods are time-consuming, costly, and require constant or at least annual repetition.

The present study suggests that muskrats can be ecologically controlled in farm ponds through manipulation of the soil texture and slope of the dam. A mechanical analysis can be made of the soil of which the embankment will be composed. If the soil contains enough clay to hold permanent or temporary burrows, a slope less than 10° should prevent burrowing activity. Much steeper slopes would be justified if the soil contained more than about 70% sand.

However, dams constructed with a slope of 10° or less must be very wide in order to gain sufficient height to be functional and thus are expensive. Embankments constructed of soil containing a high percentage of sand can have a steep slope and still be free of burrows, but such soils make the least satisfactory dams. These constructions tend to leak and erode.

In embankments where the soil dictates that the slope should be held below 10°, construction of a berm at the base of the dam might be preferable to building a very wide dam (Figure 10A). Burrowing activity is discouraged because the muskrat is forced to dig a great dis-

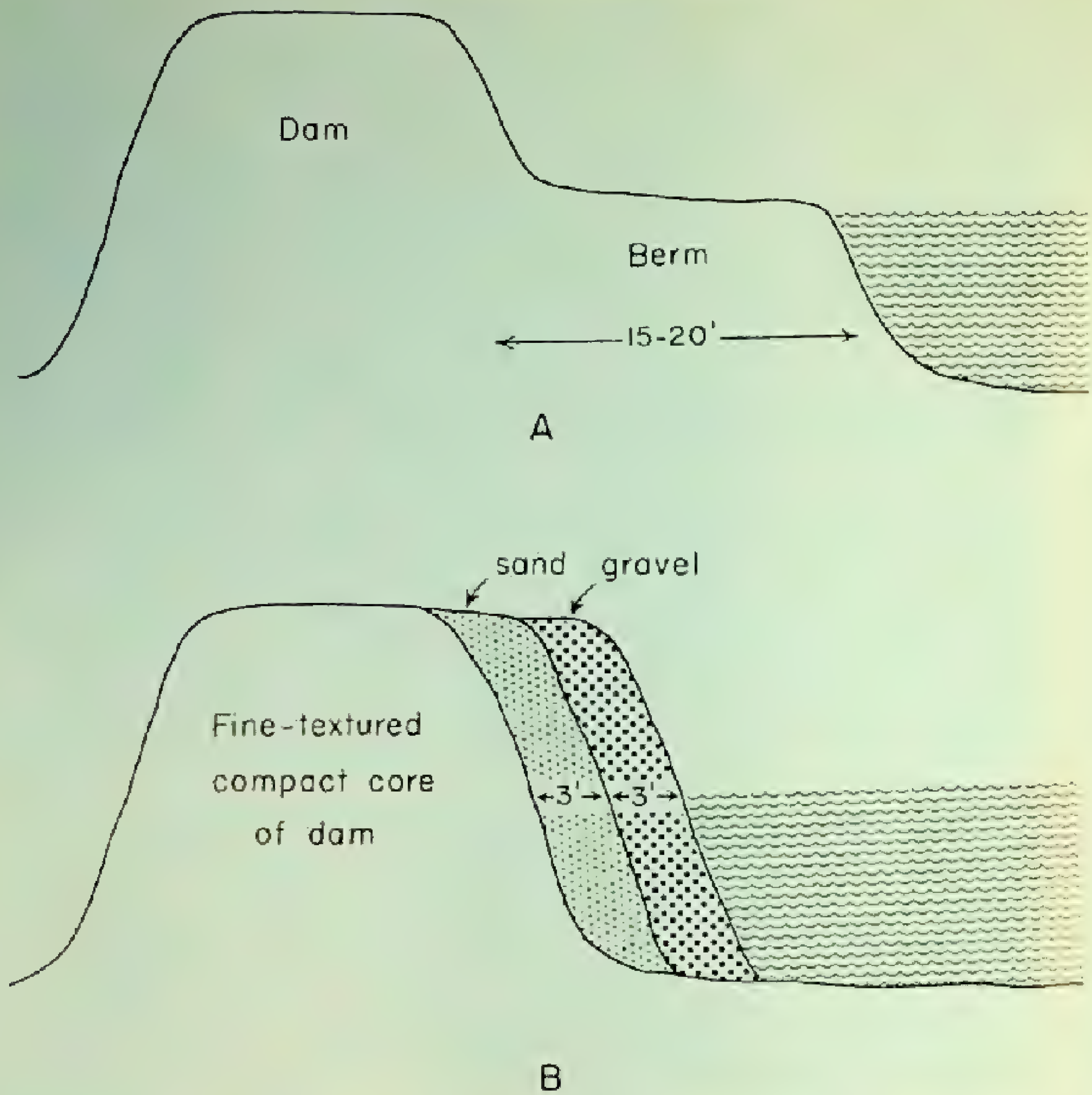

FIGURE 10—Two embankments designed to reduce muskrat damage. A, construction of a berm at the base of the main dam; B, addition of layers of coarse material to the fine-textured core of the dam.

tance into the embankment before it can rise above the water level and obtain air. In observations of such dams, no case was found where a muskrat crossed the berm and constructed a burrow in the embankment above the level of the water. However, when the water level was allowed to rise until the berm was completely under water, burrows were built in the main dam and maintained long after the water level receded. Since the water in farm ponds is often used for irrigation and consequently fluctuates greatly, use of a berm would not be practical in most situations.

Because dams cannot feasibly be sandy or as flat as 10°, a dam constructed with the specifications shown in Figure 10B would probably be the most effective embankment. A compact core of soil containing a high percentage of clay can be bordered with a 2- to 3-ft thick layer of sand, in order to prevent burrowing activity from extending into the clay core. An additional layer of gravel, cobbles, or stones could be placed over the sandy layer to prevent erosion. Such a method should be

relatively inexpensive, especially if sand and gravel are readily available at a nearby stream bottom. The two layers of coarse-textured materials could also be added to already constructed dams which are currently being damaged by muskrat burrows, in order to prevent future damage.

SUMMARY

Muskrat burrows and tule lodges in farm ponds in Siskiyou County, California, were examined. Three types of burrows were described: (i) breeding burrows, large complex systems used as living and nesting areas throughout the year; (ii) winter burrows, smaller systems of short duration used as living areas primarily during the winter; and (iii) feeding burrows, small short-lived excavations used as refuges when feeding. Most of the winter burrows, feeding burrows, and tule lodges were constructed in late fall and collapsed or became inactive in early spring. Breeding burrows remained intact and active throughout the year.

Mechanical analyses of soil taken from individual burrow sites indicated that the permanent breeding burrows were constructed in soil containing more clay and less sand than soils at the locations of temporary winter and feeding burrows. The longevity of these temporary burrows was inversely related to the percentage of sand in the soil. Either an excessive amount of sand or a slope less than 10° limited muskrat burrowing activity entirely. Temperature fluctuations were much larger in temporary burrows because of the greater thermal conductivity of sand.

The muskrats occupying breeding burrows were larger and usually older than the individuals occupying winter burrows. Overall size appeared to be more important than age in territorial interactions, since large subadults displaced small adults. Both breeding and winter burrows tended to occur in closely adjacent groups of two, with a male in one burrow and a female in the other. When an individual was trapped and removed, another of the same sex usually moved into the vacant burrow.

It is hypothesized that the large numbers of new temporary burrows built in the late fall were constructed by subadults leaving the parental burrows during the annual fall dispersal. The young were apparently excluded during a short period of increased fighting and territoriality among the adults in late fall.

Muskrat damage in farm ponds can possibly be reduced by construction of a berm at the base of the main dam or by adding layers of coarse-textured material to the main core of the dam.

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REFERENCES

Baver, L. D. 1956. Soil physics. 3rd ed. John Wiley and Sons, Inc., New York. 489 p.

Beer, James R., and Roland K. Meyer. 1951. Seasonal changes in the endocrine organs and behavior patterns of the muskrat. Jour. Mammal., 32 (2) : 173–191.

Beshears, W. Walter, Jr., and Arnold O. Haugen. 1953*a*. Muskrats in relation to farm ponds. Jour. Wildl. Mangt., 17 (4) : 450–456.

———. 1953*b*. Muskrats in your farm pond. Ala. Cons., 25 (1) : 4–5, 22.

Black, C. A. (Editor-in-Chief). 1965. Methods of soil analysis. Part 1. Physical and mineralogical properties, including statistics of measurement and sampling. Amer. Soc. Agron., Inc., Madison, Wisconsin. 770 p.

Day, Paul R. 1950. Physical basis of particle size analysis by the hydrometer method. Soil Sci., 70 : 363–374.

Errington, Paul L. 1963. Muskrat populations. Iowa State Univ. Press; Ames, Iowa. 665 p.

Godfrey, Gillian, and Peter Crowcroft. 1960. The life of the mole. Museum Press, London. 152 p.

Grinnell, Joseph, J. S. Dixon, and J. M. Linsdale. 1937. Muskrats, p. 728–763. *In* Joseph Grinnell, J. S. Dixon, and J. M. Linsdale, Fur-bearing mammals of California. Univ. Calif. Press. Vol. 2.

Johnson, Charles E. 1925. The muskrat in New York: its natural history and economics. Roosevelt Wildl. Bull., 3 (2) : 193–320.

Kersten, Miles S. 1949. Thermal properties of soils. Univ. Minn. Inst. Technol., Bull. 28.

Kilmer, Victor J., and Lyle T. Alexander. 1949. Methods of making mechanical analyses of soils. Soil Sci., 68 : 15–24.

Miller, Richard S. 1964. Ecology and distribution of pocket gophers (Geomyidae) in Colorado. Ecology, 45 (2) : 256–272.

Miller, Richard S., and Henry E. Bond. 1960. The summer burrowing activity of pocket gophers. Jour. Mammal., 41 (4) : 469–475.

Nagel, W. O. 1945. Controlling muskrat damage in ponds. Mo. Cons., 6 (4) : 10–11.

Nicholson, William R., and David E. Davis. 1957. The duration of life of muskrat houses. Ecology, 38 (1) : 161–163.

Olsen, Peter F. 1959. Dental patterns as age indicators in muskrats. Jour. Wildl. Mangt., 23 (2) : 228–231.

Sather, J. Henry. 1958. Biology of the Great Plains Muskrat in Nebraska. Wildlife Monogrs. No. 2 : 35 p.

Seton, Ernest Thompson. 1929. Lives of game animals. Vol. IV, Part II. Doubleday, Doran, and Company, Inc., p. 569–601.

Watson, E. B., M. E. Wank, and Alfred Smith. 1923. Soil survey of the Shasta Valley Area, California. U.S. Dept. Agric., Bur. Soils, Washington. 152 p.

Wilson, Kenneth A. 1960. Controlling muskrats in farm ponds. Wildl. in North Carolina, 24 (8) : 16–17.

Calif. Fish and Game, 55(3) : 197–212. 1969.

LIFE HISTORY STUDIES OF THE LAHONTAN REDSIDE, *RICHARDSONIUS EGREGIUS*, IN LAKE TAHOE[1]

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Lahontan redsides occur in Lake Tahoe in greatest numbers along the rocky shoreline and around piers during the summer. Few redsides were taken in water more than 40 ft deep or in areas of extensive sandy habitat. The redsides apparently spend the winter in a torpid state at depths of 10 to 50 ft. Spawning begins in early June, reaches maximum activity during late June, and continues at a slow rate through July and into August. Redsides form large aggregations and spawn over gravel and rocks along the shoreline and in tributaries. Males on the spawning grounds outnumber females. For 16 specimens the estimated average number of eggs per female was 1,125. A pronounced bilateral variation was evident in weight of the ovaries and number of eggs. The average lengths of males at annuli I, II, III, and IV were 33, 48, 65, and 73 mm, respectively. The corresponding lengths of females were 35, 52, 68, and 78 mm. The summer diet consisted mainly of surface foods (especially adult Diptera, Coleoptera, and Hymenoptera), chironomid larvae and pupae, and crustaceans. Hybrids between all three of the cyprinids in Lake Tahoe were discovered.

INTRODUCTION

The Lahontan redside, *Richardsonius egregius* (Girard), is a small cyprinid endemic to the Lahontan drainage system in western Nevada and adjacent northeastern California. Information on the ecology and life history of this species is rather scarce. Snyder (1917) offered a few notes on its distribution, spawning, and food habits. As part of his study on Lake Tahoe fishes, Miller (1951) considered food habits and some aspects of distribution and reproduction. This report considers the age and growth, food habits, reproduction, distribution, and movements of the Lahontan redside (Figure 1) in Lake Tahoe.

FIGURE 1—The Lahontan redside, *Richardsonius egregius* (male; 65.7 mm SL). *Photograph by Scientific Photographic Laboratory, University of California, Berkeley.*

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Lake Tahoe is situated in the Sierra Nevada at an elevation of 6,225 ft above sea level (for a map of Lake Tahoe see Cordone and Frantz, 1966). It is 21.6 miles long and 12 miles wide, and has a mean depth of about 1,027 ft and a maximum depth of 1,645 ft. It is an oligotrophic lake, and Secchi disk readings average about 90 ft (range 50 to 135 ft; McGauhey et al., 1963). Lake Tahoe has a single outlet, the Truckee River, which empties into Pyramid Lake, a remnant of pluvial Lake Lahontan.

Food habit studies (Miller, 1951, and Lake Tahoe Fisheries Study, unpubl. data) indicate that the redside is a minor component in the diet of Tahoe game fishes. It is insignificant in the diet of lake trout (*Salvelinus namaycush*), the principal game species (Weidlein, Cordone, and Frantz, 1965), and only moderately important in the diet of rainbow trout (*Salmo gairdnerii*).

METHODS

Redsides were collected by several techniques, including traps, gill nets, trawls, seines, and rotenone. The California and Nevada Fish and Game Departments conducted year-round fish collections as part of their study of Lake Tahoe fishes. Bottom gill nets were set monthly from July 1962 through July 1964 at various depths from 25 to 500 ft, with occasional sets made in deeper water. These nets consisted of multifilament nylon panels, which were 100 to 200 ft long by 11 ft deep. Each net contained panels of ¾-inch and 1-inch meshes (stretch measure), suitable for taking redsides, plus a number of larger meshes. In addition, gill nets made of monofilament nylon were fished in the limnetic zone of the lake throughout 1964. The panels were 50 ft long by 22 ft deep, and mesh sizes were 1 inch and larger. These nets were usually set in pairs, one at the surface, the other at either 50 or 100 ft.

Small, cylindrical, wire minnow traps (8½ x 17 inches) and large, rectangular traps (36 x 18 x 18 inches) were used to collect redsides. The large traps were usually set with the bottom gill nets. Traps were also set for a period of 4 or 5 days each month during parts of 1963 and 1964 at the Tahoe Boat Company pier (Tahoe City) and Obexer's pier (Homewood). Various baits were used in the traps, including bread, cheese, and canned dog food.

A 25-ft semiballoon otter trawl was used for bottom trawls at depths from 100 to 500 ft, conducted regularly during 1963, 1964, and part of 1962. Rotenone was used in selected shoreline stations from 1963 through 1966. The sample areas were encircled with long seines prior to the application of the rotenone; Baker (1967) gives additional details on sampling with rotenone.

Fecundity estimates were made from the ovaries of preserved specimens. A sample of each ovary was removed from three different regions, and comprised approximately one-fourth of the whole ovary. The eggs in the sample were counted, and the total number of eggs in the ovary was calculated by simple proportion. All weights were measured to the nearest 0.005 g. An actual egg count of the eggs in one pair of ovaries was made. The estimated numbers of eggs were 288 and 705 compared with actual counts of 293 and 664, respectively.

All scale samples were taken from preserved specimens and were consistently removed from the area below the origin of the dorsal fin and above the lateral line on the left side of each specimen. Scales were dry-mounted between two glass slides held together with cellophane tape and examined with a projection apparatus. The annuli, focus, and edge of each scale were marked on tagboard strips placed along the anterior field. A nomograph was used to estimate body lengths at each annulus. Since the relationship between standard length and length of the anterior field of the scale was found to be linear (although points on the graph were widely scattered), the length estimates were used without correction. In using the nomograph, the focus marked on the tagboard strip was set at 17, since scale formation occurred at a standard length of about 17 mm, as shown by staining a series of young specimens with alizarin red.

Food habit studies were based on the contents of the first of the three loops of the gut, since a distinct stomach is absent in the redside. Initial attempts at weighing the gut contents proved inadequate because of the small quantities involved. Consequently, a grid placed beneath the container on the microscope stage was used to make an estimate of the total volume of the ingested material and of the volume of each category after sorting. The material was distributed to a uniform depth and density in each case.

DISTRIBUTION

Spatial Distribution

Lahontan redsides inhabit the littoral zone of Lake Tahoe, primarily areas where the substrate is rocky, or where cover is afforded by piers. Traps set in rocky areas generally took many redsides, whereas traps set in sandy habitat took few or none. Observations made while free diving (mask, fins, snorkel) revealed an absence of redsides in sandy habitat, even where such areas were adjacent to rocky shoreline. Redsides predominated around piers, and were the most common minnow taken in fishermen's traps. Hence, the species serves as the primary bait used by deepline anglers fishing for lake trout.

Extensive trappings revealed that redsides were most abundant in shallow water to depths of 30 or 40 ft. Futhermore, of 112 sets with bottom gill nets and 75 sets with open-water gill nets, only 11 caught redsides. One redside was caught 4 ft below the surface in an open-water set made 300 yards offshore where the depth was 180 ft. The remaining 10 sets were bottom sets, 9 of which were made at depths of 25 ft or less. One set caught six redsides at a depth of 115 to 120 ft, the greatest depth at which redsides were taken in Tahoe. This set was made in the northwest part of the lake.

Only two trawl hauls caught redsides. Both of these were made in 1962, one at a depth of 15 to 20 ft, the other at 65 to 100 ft. No redsides were taken in 109 trawls made in 1963 and 120 trawls in 1964.

Daytime observations made while free diving indicated that redsides which congregated near the shoreline to depths of 4 or 5 ft formed very loose aggregations. Over deeper water, the schools were much more distinct and generally were found within a few ft of the surface. In such schools, I often observed surface feeding, as individuals would dart to the surface and immediately return to the school.

Seasonal Distribution

Redsides were abundant around piers and rocky shores from late spring to early fall, but were very scarce during the remainder of the year. The monthly minnow trappings at the piers reflect seasonal abundance (Figure 2). Redsides became relatively numerous in mid-May, coincident with a rise in surface temperatures from the high 40's to the low 50's (F). Peak numbers occurred during the months of June, July, and August, tapering off to low activity by late November, when temperatures dropped to the high 40's. Since the traps have several inadequacies as a sampling tool, the seasonal pattern described should be regarded as a rough approximation of the overall situation in the lake. A notable exception to the pattern seen at the piers was a collection made on April 10, 1962, in which two traps set for 4.5 hr in 30 ft of water took 338 redsides at Zephyr Cove (water surface temperature 46 F).

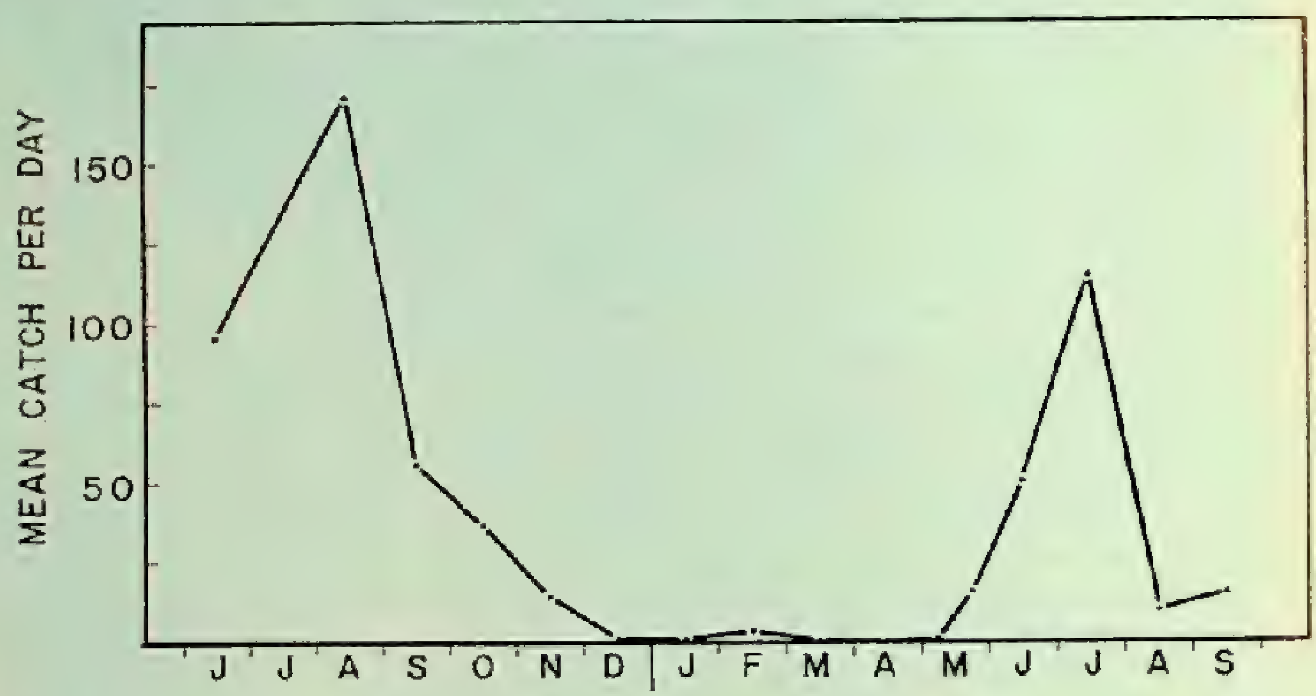

FIGURE 2—Seasonal variation of Lahontan redsides caught in traps set at piers in Lake Tahoe from June 1963 through September 1964.

Data from traps set in winter and sampling with rotenone in March 1966 suggest that the redsides spend the winter offshore at depths from 10 to 50 ft in rubble and boulder areas. Such areas commonly grade into sand at 25 to 30 ft but in some parts of the lake extend out much farther. It seems clear that the redsides are inactive during the winter, since extensive efforts to trap them met with slight success. Crossman (1959) proposed that the redside shiners (*R. balteatus*) of Paul Lake, British Columbia, spend the winter offshore at depths of about 30 ft; during mid-May they move onto the shoals.

Distribution of Young

Young redsides were observed in shallow and quiet water along the lake margins and in pools at the mouths of creeks. They were most numerous where there were accumulations of organic debris.

Many young and some adult redsides were collected in shoreline rotenone sampling from 1963 through 1966 (summarized by Baker, 1967). Redsides were second in importance to Lahontan speckled dace (*Rhinichthys osculus robustus*). "Overall, 70.1% of the fish were dace, 14.7% Lahontan redside . . . , 7.1% Piute sculpin (*Cottus beldingii*), 3.9% Tahoe sucker (*Catostomus tahoensis*), 3.2% rainbow trout (*Salmo gairdnerii*), and the remaining 1.0% tui chub (*Siphateles bicolor*) [now *Gila bicolor*], brown trout (*Salmo trutta*), mountain whitefish (*Prosopium williamsoni*), and eastern brook trout (*Salvelinus fontinalis*)."

Large concentrations of immature redsides and other species were observed off Lake Forest, a marshy area on the north shore of the lake. I made several collections here using a one-man seine. Of 337 fishes collected on July 1, 1964, 63% were dace, 22% suckers, 8% redsides, and 7% chubs. The species varied in abundance at different times. On July 17, 1964, I collected 462 fishes, of which 33% were redsides, 32% suckers, 22% dace, and 13% chubs. Later in the summer these populations were much reduced. By mid-August young-of-the-year were evident in great numbers, and most of the larger fishes had left the area.

I also collected in Truckee Marsh, located at the mouth of the Upper Truckee River on the south shore of the lake. Here in July and August of 1964, I collected six species: 66 tui chubs, 52 brown bullheads (*Ictalurus nebulosus*; 25-81 mm FL), 49 golden shiners (*Notemigonus crysoleucas*; 20-76 mm FL), 29 Tahoe suckers, 10 redsides, and 8 dace. The golden shiner and brown bullhead seem to be established in Truckee Marsh; presumably they were introduced by bait fishermen.

REPRODUCTION

Spawning Season

Spawning begins in early June. In 1964, redsides were first noted spawning on June 12 at Agate Bay but only casual observations were made before that date. On June 4, 1966, spawning and redside embryos were observed in Taylor Creek. It seems possible that spawning might begin as early as the end of May in years of exceptionally warm springs. Maximum spawning activity occurred in the third and fourth weeks of June in 1964. By the second week of July, activity had declined sharply. However, spawning continued at a slow pace for a few more weeks. A ripe female was taken as late as August 6, 1964, at Pebble Beach. At that time, only small numbers of fish were present on the spawning grounds.

Throughout the spawning period, samples of redsides were collected from the spawning grounds and tested for ripeness. Fish were considered ripe if gametes flowed freely from the vent when gentle pressure was applied to the sides of the living specimen. Nearly all males were ripe throughout the spawning season, but often females which were not ripe were found. Presumably, the unripe females either were not yet ready to spawn, or were spawned out, depending on whether it was early or late in the season.

Murphy (1963) conducted a study of trout survival in Taylor Creek, one of the larger tributaries located near the southern end of Lake

TABLE 1

Collections Made at Redside Spawning Sites in Lake Tahoe

Date	Time	Surface temp. (F)	Number of redsides						Associated species		
			Males (mean SL; range SL)		Females (mean SL; range SL)		Total no.	Males:females	Chub	Dace	Sculpin
Agate Bay (collections made with traps)											
June 12, 1964	11 a.m.	55	24	66.2; 54-75	2	73.0; 71-76	26	12:1	0	5	0
June 12, 1964	2 p.m.	57	46	67.3; 61-75	1	85.0	47	46:1	0	43	0
June 19, 1964	2 p.m.	58	--		--		24	--	0	233	0
June 29, 1964	4 p.m.	62	8	66.2; 63-69	0		8	--	0	11	0
July 5, 1964	11 a.m.	59	6	65.8; 61-70	12	75.3; 63-88	18	0.5:1	3	10	0
July 10, 1964	5 p.m.	--	12	65.7; 58-78	5	74.2; 65-85	17	2.4:1	0	26	0
July 30, 1964	1 p.m.	65	4	60.0; 54-65	0		4	--	0	1	0
Aug. 10, 1964*	5 p.m.	70	4	57.8; 48-67	13	71.3; 58-88	17	0.3:1	0	7	0
Sept. 9, 1964*	3 p.m.	66	7	60.5; 42-73	9	63.3; 49-79	16	0.8:1	0	15	0
Homewood (collection made with seine)											
June 25, 1965	9 p.m.	52	14	63.4; 56-71	11	61.0; 57-77	25	1.3:1	3	0	11
Pebble Beach (collections made with seine)											
July 9, 1964	4 p.m.	62	325 for 73:	65.4; 51-78	3		328	108:1	17	20	1
July 19, 1964	6 p.m.	65	262 for 101:	64.3; 50-77	25	63.2; 55-71	287	10.5:1	4	0	6
June 23, 1965	10 p.m.	56	192	66.7; 56-78	13	65.9; 59-75	205	14.8:1	1	6	0
June 24, 1965	8 p.m.	56	25	64.7; 58-74	4	72.0; 69-80	29	6.3:1	0	0	6
June 24, 1965	10 p.m.	54	138		11		149	12.5:1	168	1	0
June 25, 1965	10 p.m.	53	50	65.6; 59-78	7	66.2; 56-75	57	7.1:1	100	1	0
Taylor Creek (collections made with seine)											
June 14, 1964	2 p.m.	59	16	68.5; 64-77	1	70.0	17	16:1	0	0	0
June 14, 1964	5 p.m.	60	8	67.3; 63-74	4	62.1; 59-67	12	2:1	0	0	0
June 14, 1964	5 p.m.	60	16	67.5; 57-74	29	66.6; 60-81	45	0.6:1	0	0	0
July 18, 1964	2 p.m.	72	26	63.0; 51-76	4	69.4; 65-75	30	6.5:1	0	4	0
June 25, 1965	10 a.m.	56	130	64.7; 55-77	26	63.4; 54-79	156	5:1	0	1	0
June 25, 1965	11 a.m.	57	155	64.0; 56-75	10	58.8; 52-71	165	15.5:1	0	0	0
Burton Creek (collections made with seine and trap)											
June 2-5, 1965	--	--	29	66.7; 59-78	75	74.9; 56-90	104	0.4:1	0	65	0
June 24, 1965	6 p.m.	56	16	64.7; 57-75	3	62.7; 55-69	19	5.3:1	0	2	0

* These collections were made after the spawning season was apparently over.

Tahoe, during the summer of 1940, using screens to fence off a section of the stream. He reported that the redside, ". . . breeds all through the summer or at least to the end of August . . . . They suffered a tremendous mortality of adults during August; scores of dead were washed against the screens on some days and many dead were on the stream bottom." I never observed more than a few dead redsides in the stream, but I did not use a screen or other device.

Spawning Habitat

Throughout the breeding season a few lake and stream spawning sites were investigated repeatedly (Table 1). An important spawning site was located in Agate Bay at a spot 0.7 miles west of the Tahoe Vista Post Office. The substrate consisted largely of silt-free gravel and rubble up to 3 or 4 inches in diameter. The gradient was gradual; at a distance of several ft from shore the depth was 2 ft. Spawning was observed over a 40-ft section of this shoreline. No spawning activity was noticed in adjacent areas which were deeper and deficient in the smaller sizes of rock and rubble.

At Pebble Beach, between Ward and Blackwood Creeks, the substrate consisted almost entirely of rounded stones 2 to 3 inches in diameter; no silt was present. The gradient was steeper than at Agate Bay. At a distance of 7 ft from shore the water depth was about 3 ft.

No attempt was made to locate all spawning sites around the lake. The great size of Lake Tahoe and the difficult accessibility of much of the shoreline made it nearly impossible to do so, but there are many shoreline areas which are similar in substrate and water characteristics to those described above. Cordone and Frantz (1968) discuss the shoreline habitat of Lake Tahoe.

In Taylor Creek the redsides usually spawned over the upsloping bottom at the downstream end of pools, where the substrate consisted largely of sand and gravel. Larger stones occurred in some spawning sites, and very little silt was found in any of them. Spawning activities and the eggs of redsides were also observed in Burton Creek. During the breeding season, redsides were noticed in Third and Meeks Creeks. These two small streams appeared to have suitable spawning sites, but no eggs were found in the substrate. Since I examined the streams only briefly, evidence of spawning may have been overlooked.

Sexual Dimorphism and Coloration

The most striking feature of a redside in spawning condition is the red-orange lateral stripe. Breeding males are more colorful than females. Males possess a bright red stripe and brassy coloration just before and behind the base of the pectoral fins and in the suborbital area, which is sometimes streaked with red. The skin over the first pectoral ray is very dark in the males. The pectoral rays of breeding females are not as dark, and the red stripe is generally not as intense as in the male; the brassy coloration is usually absent. Sexual dimorphism also exists in the length of the pectoral fins (Figure 3), and to a lesser extent in the length of the pelvic fins. The pectoral fins of the male reach or nearly reach the base of the pelvic fins when the former are

depressed. When the pelvic fins of the male are depressed, they extend to the vent. The females generally have shorter pectoral and pelvic fins. The females have a bulging abdomen when in spawning condition, and the region around the vent is more distended than in the male. The females tend to be longer than males. During the breeding season, both sexes develop nuptial tubercles. In the male the tubercles appear over most of the body and on the head, opercles, and pectoral fins. The tubercles of the female are not as large as those of the male and are fewer in number, being restricted largely to the body and head.

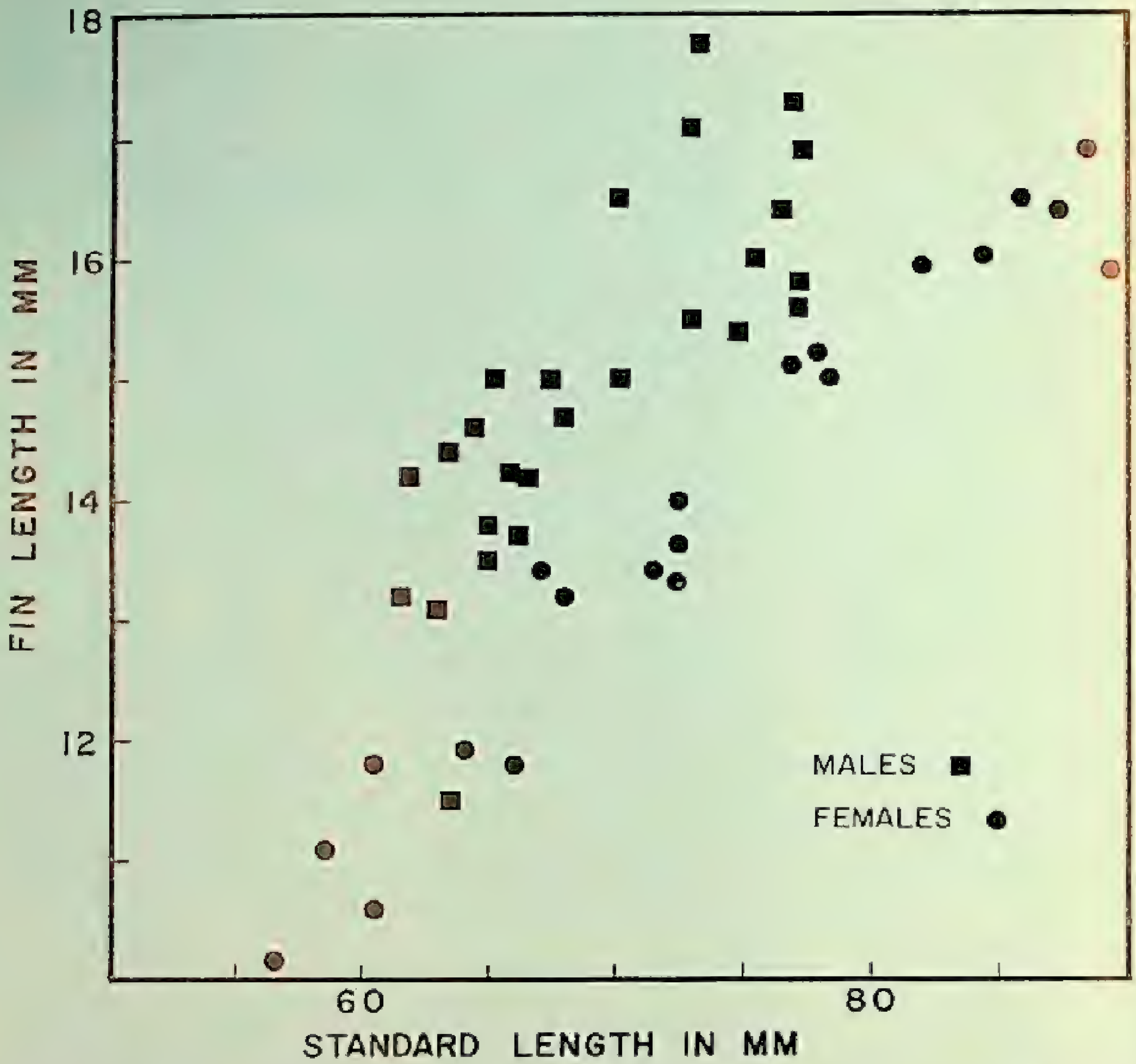

FIGURE 3—Sexual dimorphism in pectoral fin length of Lahontan redsides from Lake Tahoe.

The best external characters for distinguishing the mature sexes during nonbreeding periods are the pectoral and pelvic fin lengths. Nonbreeding individuals lack the brassy coloration, and the red stripe may be absent or nearly so.

Sex Ratios

Generally there were many more males than females on the spawning sites (Table 1). The variation in sex ratios, with females predominating

in some collections, may reflect a tendency for the sexes to school separately at times. Three collections were made in Taylor Creek on June 14. In one area the sex ratio was 16 males to 1 female, while in two other areas the ratios were 2:1 and 0.6:1.

In contrast with the situation found on the spawning sites, collections of redsides made at piers during the breeding season regularly contained more females than males. As the season progressed and breeding activity declined, an increasing proportion of males appeared at the piers.

This information suggests that the males move to the spawning sites in large numbers at the beginning of the breeding season and remain on these sites, and in breeding condition, for a long period of time. The females apparently move to the spawning sites as they ripen, returning to the piers and other habitat after they spawn. The period of time which individual spawning females remain on the sites could not be determined.

Spawning Behavior

Observations of the spawning behavior of redsides were conducted on several occasions. Preparations of the spawning gravel did not occur. Pairing did not take place, but instead large, dense groups of redsides moved rapidly over the substrate in shallow water.

At the Agate Bay site, large aggregations were observed during the height of the spawning season, but actual breeding behavior occurred in groups of approximately 20 to 100 fish. The fish swam over the rubble in water 3 to 15 inches deep, staying close to the bottom. Much chasing and crowding was evident, and groups changed direction every few seconds. Often the erratic chasing would cease, and the fish would appear to force themselves against the substrate, pressing into nooks and crevices between the rocks. It was not possible to observe actual oviposition, but it probably accompanied this behavior.

At Pebble Beach the pattern of behavior was similar. Much spawning took place at the edge of the shoreline in water so shallow that the dorsal parts of the fish were exposed. When moving along the shoreline, the redsides often traveled at a distance of 3 to 4 ft from the beach, returning to shallow water to resume spawning. Stream spawning observed at Taylor Creek was similar, but movement over the gravel was much less extensive.

At Agate Bay and Pebble Beach, day-to-day fluctuations in the numbers of spawners were noted. To some extent, this variation was due to the weather. On windy days wave action was heavy, and the redsides moved from the shallow water. On a couple of such occasions, I set traps in the rocks beyond the spawning area at depths of 10 ft or more and caught redsides. Sometimes they were absent or scarce when the weather did not seem to be a factor.

No indication of diurnal variation in the intensity of spawning activity was apparent from superficial observations. Spawning was observed throughout the day until darkness, when visual observation was no longer possible. Seine hauls made after dark took ripe redsides on the spawning grounds.

Other cyprinids were often collected with the redsides on the spawning sites (Table 1), but only at Agate Bay were interactions between species observed. Speckled dace were often seen with the redsides, though the two species tended to group separately. The dace and redsides frequently came in contact with each other. On a few occasions, the redsides appeared to be chasing the dace. I examined some of these dace and found them to be ripe, but since no dace eggs were found in the substrate, I am not certain they were spawning at this time.

Suckers and redsides shared many of the gravel bars at Taylor Creek, and eggs of both species were found together in the substrate. In some areas of the stream, dace were found with the redsides. I did not see aggressive behavior between the species. Snyder (1917) mentioned redsides following female suckers and feeding on their eggs.

Fecundity

Fecundity estimates were made from preserved specimens which had been collected just before the beginning of the spawning season. Only mature eggs, distinguished by their large size, rounded shape, and yellowish color, were counted.

The average number of eggs contained in both ovaries of 16 females was 1,125, with a range of 180 to 1,695 (Table 2). The left ovary had an average number of 350 eggs (0–918), compared with an average of 775 eggs (600–1,371) in the right ovary. In 4 cases out of 16, the left ovary was much reduced, and in 2 cases the left ovary contained no mature eggs. This pronounced bilateral variation was reflected in ovary weights. Based on 25 samples, the right ovary comprised an average of 5.6% of the total body weight, compared with a mean of 2.5% for the left ovary.

TABLE 2

Estimated Number of Eggs in Ovaries of 16 Female Redsides

Standard length (mm)	Number of eggs		
	Total	Left	Right
83.0	1,236	43	1,193
79.5	1,695	918	777
78.0	1,113	193	920
76.5	1,556	909	647
75.5	711	267	444
74.5	1,523	704	819
73.0	1,371	0	1,371
72.0	1,278	243	1,035
71.5	1,235	635	600
71.0	1,096	433	663
70.0	845	0	845
68.5	993	288	705
67.5	937	189	748
67.0	1,135	642	493
64.5	1,091	28	1,063
54.5	180	107	73
Averages	1,125	350	775

Seasonal Cycle in Gonad Weight

The gonad weights of 196 males and females collected at various times of the year were expressed as a percentage of body weight. Ovaries varied seasonally from about 3 to 11%, and testes varied from 0.5 to 3.5%. The gonads increased in weight during the months of March, April, and May.

HYBRIDIZATION BETWEEN LAKE TAHOE CYPRINIDS

In the course of the life history study, hybrids between all three of the cyprinids in Lake Tahoe were discovered. Specifically, these hybrids are *Richardsonius egregius* × *Gila bicolor*, *Rhinichthys osculus* × *R. egregius*, and *R. osculus* × *G. bicolor*.

The *R. egregius* × *G. bicolor* hybrid was noted many years ago. Snyder (1917) described it as a new species, *R. microdon*, but Hubbs and Miller (1943) subsequently identified it as a hybrid. Miller (1951) reported the *R. osculus* × *R. egregius* hybrid from Lake Tahoe, and Calhoun (1940) reported it from Five Lakes, Placer County, California. Hopkirk and Behnke (1966) reported the *R. osculus* × *G. bicolor* hybrid from Lake Tahoe, based on specimens collected during this study.

Hybrids may be distinguished by coloration, proportion of body parts, and gill raker number. A manuscript dealing with the morphometry of these hybrids, frequency of occurrence, and possible causes of hybridization is in preparation by the author (in collaboration with J. D. Hopkirk).

AGE AND GROWTH

Difficulty was encountered in discerning annuli, and the estimates given here should be regarded as preliminary findings. The most reliable indication of an annulus was the cutting across of incomplete circuli by other circuli upon the resumption of growth. Assigning ages to the scales was difficult because cutting over and incomplete circuli sometimes occurred in what appeared to be nonannular regions of the scales.

The scales of 119 specimens were examined, but 16 were discarded as unreadable. The average standard lengths (mm) at each annulus were estimated as follows (number of specimens in parentheses).

Annulus	I	II	III	IV
Male	33.3 (42)	48.4 (33)	65.0 (20)	73.3 (4)
Female	35.1 (61)	52.4 (53)	67.5 (44)	77.8 (13)
Combined	34.4 (103)	50.9 (86)	66.7 (64)	76.7 (17)

Females averaged slightly larger than males, although the magnitude of the difference was not consistent between year classes, and sample sizes were small. The difference in length at annulus I was not expected. Annulus formation seems to be completed in May.

Length-frequency distributions were not useful in determining age classes (Figure 4). However, they do show that females average somewhat larger in size than males.

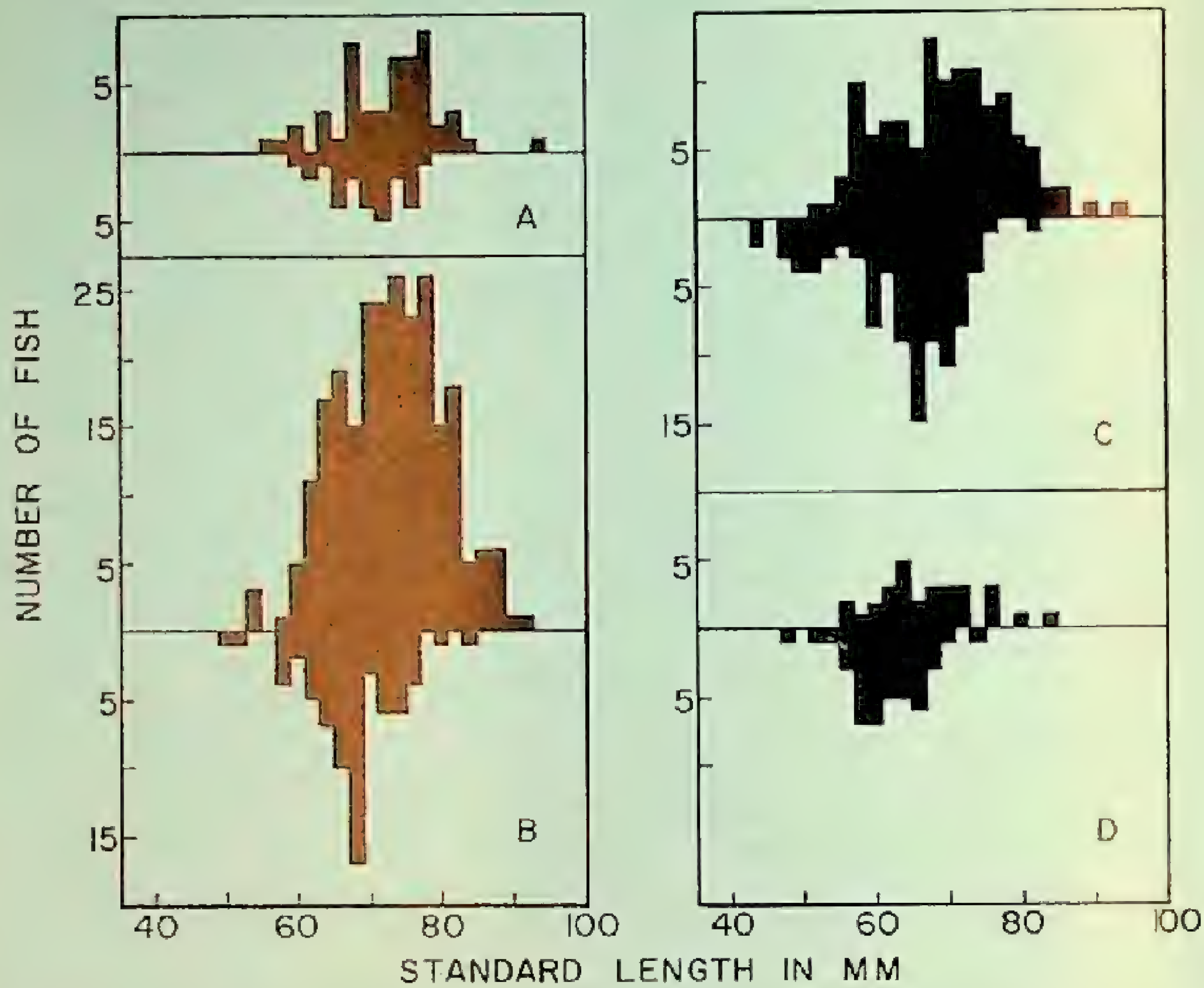

FIGURE 4—Length-frequency distributions of Lahontan redsides in four of the samples taken at piers in Lake Tahoe (females above line, males below). A, May 25–29, 1964; B, June 15–22, 1964; C, July 17–24, 1964; D, September 23–25, 1964.

The larger size of females is apparent from both the scale data and the length-frequency distributions. There is a regular increase in the number of assigned annuli as the length of fish increases, which supports the validity of the assignments.

A comparison of these growth estimates with the lengths of spawning redsides (Table 1) indicates that most of the spawners are 3 and 4 years old. The small size of some spawners suggests that some redsides reach sexual maturity when they are 2 years old.

The relationship between length and weight was examined graphically (Figure 5). Separate plots of males and females revealed very slight differences in the curves, so the sexes were combined.

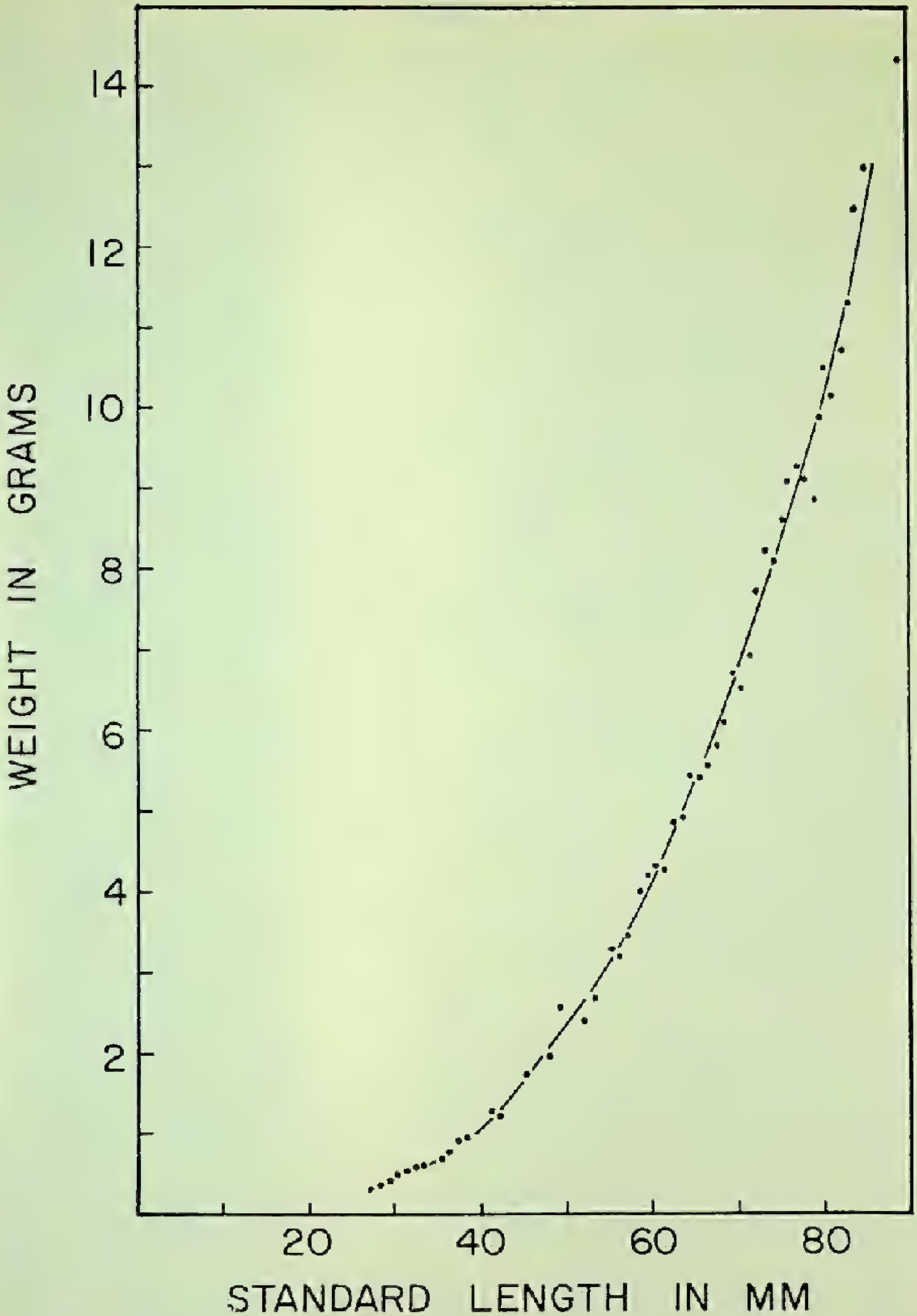

FIGURE 5—Length-weight relationship of 263 Lahontan redsides from Lake Tahoe (sexes combined; averaged at 1-mm intervals; curve fitted by inspection).

FOOD

The food of 102 specimens collected in the summer months was analyzed (Table 3). Diptera (mostly chironomids) constituted an average of 36% by volume of the diet, Coleoptera 7%, Hymenoptera 6%, and crustaceans 21%. Fragmented insect remains were identified on the basis of recognizable parts. However, a considerable amount of highly fragmented material which I could not identify often remained in the gut contents. In part, this fragmentation was due to the action of the pharyngeal teeth. In addition, many specimens were collected in minnow traps, and the bait had to be separated from the natural food items before analysis. Since the fish often were left in the traps for periods up to several hours before preservation in formalin, digestion in many cases was rather advanced.

TABLE 3

Food Habits of Lake Tahoe Redsides in Summer *

	Entire sample (N = 102; 22–88 mm st)		Lake Forest sample (N = 29; 26–65 mm st)	Excluding Lake Forest sample (N = 73)
	Percentage occurrence	Percentage volume	Percentage volume	Percentage volume
Cladocera	14	1.1	0.9	1.2
Copepoda	39	11.1	15.9	9.2
Amphipoda	4	1.1	1.5	0.9
Ostracoda	2	0.3	1.1	----
Crustacean debris	45	7.6	0.7	10.3
Arachnida	2	0.1	----	0.2
Thysanoptera	7	0.2	0.1	0.3
Hemiptera	12	0.6	1.1	0.3
Hymenoptera	15	5.7	0.4	7.8
Coleoptera	17	6.8	0.2	9.4
Diptera: adults	44	19.4	7.7	24.1
larvae and pupae	46	17.0	42.8	6.8
Insect debris	69	17.2	15.5	18.1
Animal debris	49	11.0	12.0	10.5
Sand particles	5	0.7	----	1.0
Plant matter	2	0.2	----	0.3

* Samples from June, July, August, and September 2.

Although sample sizes were inadequate to demonstrate definite size differences in food preferences, there was some indication that immature redsides depended on crustaceans and chironomid larvae to a great extent, whereas larger redsides seemed to feed more on adult Diptera (mostly chironomids), Coleoptera, and Hymenoptera. Many other adult redsides were examined, but the poor condition of the gut contents precluded detailed analysis. Fragments of Coleoptera and Hymenoptera were conspicuous, suggesting that these insects are more significant than indicated in the table. Thus, it appears that adult redsides depend heavily on flying insects as a food source. Miller (1951) found that surface foods comprised 38% by volume of the redside diet in Lake Tahoe; 28% consisted of bottom organisms, and 25% plankton. Another 8.3% he believed to be sucker eggs.

Specimens collected in the marshy area off Lake Forest showed some distinct differences from other collections (Table 3). Chironomid larvae and pupae comprised a large part (43%) of the diet of Lake Forest specimens, whereas surface foods (adult insects) were much less important. Miller (1951) also found considerable variation in redside diet in different areas of Lake Tahoe.

Small amounts of filamentous algae were found in the digestive tracts of two specimens and probably represent accidental ingestion. Cyprinid scales were found in four specimens. The size of the scales indicates that they came from fishes too large for redsides to swallow, and perhaps were ingested while the redsides were scavenging. Only one fish egg (cyprinid) was discovered.

Many specimens collected during other months of the year were examined, but the gut contents were unidentifiable because of advanced digestion and poor preservation. Three specimens (58–64 mm SL) collected on January 6 at Obexer's dock contained copepods (27% by volume), ostracods (9%), and animal debris (64%). A large part of the debris may have consisted of crustaceans, since no chitinous insect remains were evident. Redsides must derive some energy from stored fat in the winter, when insects and crustaceans are scarce. Cursory internal examination revealed accumulations of fat in the body cavities of redsides taken in late summer and fall. By spring the fat stores appeared largely depleted.

SUMMARY

Lahontan redsides in Lake Tahoe occur in greatest numbers along the rocky shorelines and around piers in the summer months. Few redsides were taken in water more than 40 ft deep or in areas of extensive sandy habitat. Redsides first become relatively numerous around the piers about the middle of May. They are most abundant in June, July, and August, but by the end of November they are scarce along the shores. They apparently spend the winter in an inactive state offshore at depths of 10 to 50 ft. Young redsides school separately from adults and are restricted to the shallow water adjacent to the shoreline in the summer. Large concentrations of young redsides and other species were found in a marshy area off Lake Forest.

Spawning begins in early June, reaches maximum activity in late June, and continues at a slow rate through July and into August. Redsides form large aggregations and spawn over gravel and rocks along the shoreline and in tributaries. Courtship and preparation of the spawning site were not evident. Males on the spawning sites outnumber females. Apparently, the males move to the spawning sites in large numbers at the beginning of the breeding season and remain there for a long time. Females move to the sites as they ripen and leave soon after spawning.

For 16 specimens, the estimated average number of eggs per female was 1,125 (range: 180–1,695). A bilateral variation in the ovaries was evident. Left ovaries averaged 350 eggs (0–918) and right ovaries 775 eggs (600–1,371). Left ovaries averaged 2.5% of body weight, compared with 5.6% for right ovaries. The main increase in weight of ovaries and testes occurred during March, April, and May.

Age and growth studies were conducted on 103 specimens. The average standard lengths of males at annuli I, II, III, and IV were 33, 48, 65, and 73 mm, respectively. The corresponding lengths of females were 35, 52, 68, and 78 mm.

Redsides taken in the summer had fed primarily on surface foods, (especially adult Diptera, Coleoptera, and Hymenoptera), chironomid larvae and pupae, and crustaceans. There was some indication that surface foods were most important in the adult diet, whereas crustaceans and chironomid larvae were primary food items of immature redsides. The diet varied in different areas of the lake.

Hybridization occurs between all three of the cyprinids in Lake Tahoe. The parental species involved are *Richardsonius egregius*, *Gila bicolor*, and *Rhinichthys osculus*.

ACKNOWLEDGMENTS

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REFERENCES

Baker, Phillip H. 1967. Distribution, size composition, and relative abundance of the Lahontan speckled dace, *Rhinichthys osculus robustus* (Rutter), in Lake Tahoe. Calif. Fish and Game, 53 (3) : 165–173.

Calhoun, Alex. 1940. Note on a hybrid minnow, *Apocope* X *Richardsonius*. Copeia, (2) : 142–143.

Cordone, Almo J., and Ted C. Frantz. 1966. The Lake Tahoe sport fishery. Calif. Fish and Game, 52 (4) : 240–274.

———. 1968. An evaluation of trout planting in Lake Tahoe. Calif. Fish and Game. 54 (2) : 68–89.

Crossman, E. J. 1959. Distribution and movements of a predator, the rainbow trout, and its prey, the redside shiner, in Paul Lake, British Columbia. Jour. Fish. Res. Bd. Canada, 16 (3) : 247–267.

Hopkirk, John D., and Robert J. Behnke. 1966. Additions to the known native fish fauna of Nevada. Copeia (1) : 134–136.

Hubbs, Carl L., and Robert R. Miller. 1943. Mass hybridization between two genera of cyprinid fishes in the Mohave Desert, California. Pap. Mich. Acad. Sci. Arts, and Let., 28 : 343–378.

McGauhey, P. H., Rolf Eliassen, Gerard Rohlich, Harvey F. Ludwig, and Erman A. Pearson. 1963. Comprehensive study on protection of water resources of Lake Tahoe Basin through controlled waste disposal. Prepared for Lake Tahoe Area Council, Engineering-Science, Inc. 157 p.

Miller, Richard Gordon. 1951. The natural history of Lake Tahoe fishes. Stanford Univ., Ph.D. Dissertation. 160 p.

Murphy, Garth I. 1963. Trout survival in Taylor Creek, a tributary of Lake Tahoe, California. Calif. Fish and Game. 49 (1) : 16–19.

Snyder, John Otterbein. 1917. The fishes of the Lahontan system of Nevada and northeastern California. Bull. U.S. Bur. Fish., 35 : 31–86.

Weidlein, W. Donald, Almo J. Cordone, and Ted C. Frantz. 1965. Trout catch and angler use at Lake Tahoe in 1962. Calif. Fish and Game, 51 (3) : 187–201.

Calif. Fish and Game, 55(3) : 213–220. 1969.

EFFECTS OF HYDRAULIC PUMPING OPERATIONS ON THE FAUNA OF TIJUANA SLOUGH[1]

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Ghost shrimp, *Callianassa californiensis* Dana, are being harvested for bait by hydraulic pumping in Tijuana Slough, San Diego County. Collectors of shrimp by other methods have lodged complaints regarding the effects of these operations on the slough's fauna. This study reveals that pumping is not harmful if operated in accordance with the regulations of the Fish and Game Commission.

INTRODUCTION

Four species of ghost shrimp occur along the California coast but only one, *Callianassa californiensis*, is being harvested by hydraulic pumping. These shrimp are harvested in Tijuana Slough, San Diego County for sport fish bait. Three methods are used to obtain ghost shrimp: (i) digging by means of a spade, which requires considerable effort; (ii) stomping, whereby the fisherman stomps the mud to a quicksand consistency and brings the shrimp to the surface (Aasen, 1967); and (iii) hydraulic pumping. Regulations authorizing the use of a hydraulic pump to take crustaceans were enacted by the California Fish and Game Commission in 1964. Within the last 2 years numerous complaints have been lodged against ghost shrimp pumpers. These complaints vary in nature, but all merited a closer look at the ecological effects of hydraulic pumping on these shrimp and other mud-dwelling species, so this study was initiated.

PRINCIPLE OF THE PUMPING OPERATION

The hydraulic pumping equipment (Figures 1 and 2) forces a head of seawater through the nozzle into the tideland sands, which in turn forces the subterranean muds, sands, and their inhabitants to the surface. Here, the shrimp are quickly dip-netted and placed in a holding tray. Regulations state that the nozzle shall not be longer nor extended into any tideland sands to a depth greater than 5 ft and that mollusks or crustaceans, other than shrimp, shall be immediately returned to their natural habitat. It is further stated that the equipment shall not be operated by a motor exceeding 5 hp, and that the inside diameter of the intake and outlet openings of the pump shall not exceed 2 inches. Each person operating or assisting operations must have a valid commercial fishing license as well as a special permit issued by the California Department of Fish and Game.

While hydraulic pumping does create a small field of quicksand 3 to 4 ft deep and 2 to 3 ft across, danger to the public is lessened because

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FIGURE 1—Ghost shrimp pumper at work in Tijuana Slough. The nozzle is pushed below the surface and the water pressure boils the shrimp to the surface, where they are dip-netted.

the sands again become compact in 3 to 6 hr and few people other than bait collectors ever enter the slough.

Fishermen look for shrimp burrows revealed by small cones of sand, which are easily detected on the surface of the mudflat (Figure 3). The beds, located intertidally, seldom extend below low tide level or above mean high tide level. Ghost shrimp do not live in very soft mud or loose sand, for the consistency of the substrate must permit construction of burrows (MacGinitie, 1934).

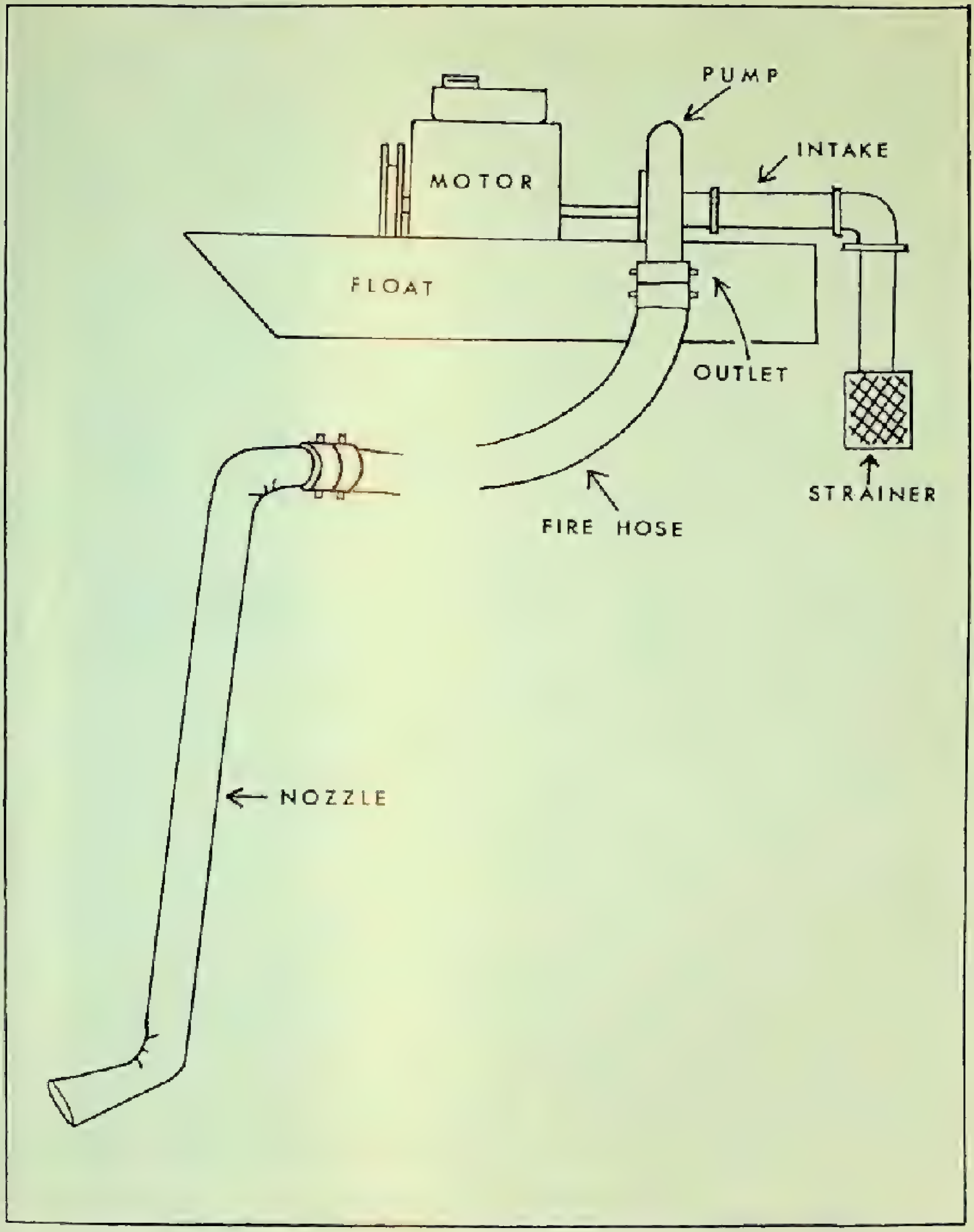

FIGURE 2—Equipment involved in the hydraulic pumping of shrimp consists of a 5-hp motor, a water pump, a hose, a nozzle, and a float.

FIGURE 3—Ghost shrimp burrows are revealed by elevated cones of sand where excavated materials have been pushed to the surface.

DATA COLLECTION

The Study Area

Tijuana Slough is located 15 miles south of San Diego and adjacent to Ream Naval Air Station, Imperial Beach, California (Figure 4). The sands in the slough are constantly changing and are often subjected to freshwater dilution as well as interrupted tidal flow caused by sandbars closing the narrow outlet. Tijuana Slough is one of the last remaining areas in southern California where commercial fishermen can harvest inshore bait. Other estuarine areas which once provided a profitable bait harvest have been subjected to harbor construction and other modifications and are no longer productive.

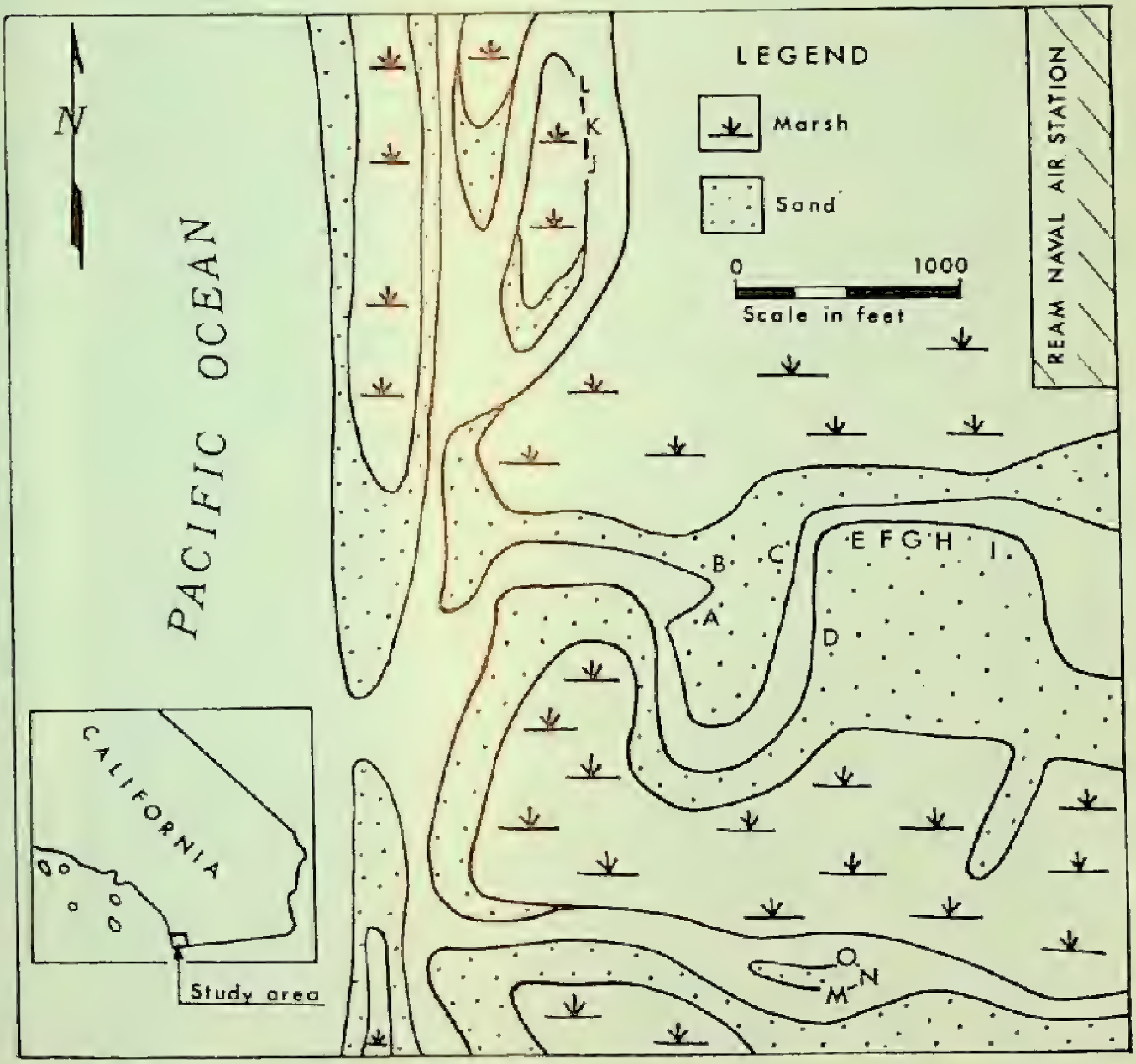

FIGURE 4—Map of the study area, showing the investigated mudflats.

In addition to ghost shrimp, purple clams, *Sanguinolaria nuttalli*, jackknife clams, *Tagelus californianus*, and rosy razor clams, *Solen rosaceus*, are harvested; however, all clams must be dug by hand or with hand tools.

TABLE 1

Numbers of Organisms Found in 10-Gal Samples from Tijuana Slough, Imperial Beach, California

Species		Sample stations														
Scientific name	Common name	A	B	C	D	E	F	G*	H	I	J†	K†	L†	M‡	N‡	O‡
Polychaeta, Nemertina																
----------	Marine worms	2								8	1					4
Arthropoda																
Scleroplax granulata§	Pea crab								5	1					1	
Callianassa californiensis	Ghost shrimp	4	2	1		1	5		4	3				2	2	5
Mollusca																
Bulla gouldiana	Bubble shell										1					
Cerithidea californica	California horn shell						2				1			14		31
Melampus olivaceus	Olive ear shell															2
Nassarius sp.	Whelk										1		1			1
Sanguinolaria nuttalli	Purple clam	1	5													
Macoma nasuta	Bentnose clam				1							2	2			
Chryptomya californica§	False mya			5	1	3	11	1	23	7						1
Protothaca lacineata	Littleneck				1							4	1			
Chione undatella	Wavy chione	2									6	1	3			
Tagelus californianus	Jackknife clam										1			2		
Echinodermata																
Dermasterias excentricus	Sand dollar				2						1					
Chordata																
Clevelandia ios§	Arrow goby		1				1				1					

* This sample had many rusty-colored nodules of sand-grease mixture.
† Samples taken from unpumped areas.
‡ Samples taken from areas pumped 3 to 4 weeks previously.
§ Species known to live commensally with ghost shrimp.

Sampling Method

I took samples from heavily pumped areas to compare with samples from areas where relatively little or no pumping had occurred. It was very difficult to find areas where little pumping activity had taken place, since most workable areas showed signs of having been worked. I took samples directly from holes that had been pumped 3 to 4 weeks previously. The other sample sites were selected at random. To take a sample, I forced a 10-gal can with the bottom removed into the substrate and carefully removed the "mud" with a small shovel. The sample was washed through $\frac{1}{4}$- and $\frac{1}{8}$-inch mesh screens. The animals were preserved in 70% isopropyl alcohol and labeled for subsequent identification. I identified and enumerated all organisms found (Table 1).

DISCUSSION

The major ghost shrimp beds are not found in the same areas as the purple clam or jackknife clam beds. Purple clam beds are located more in the subtidal zone, while jackknife clams occur in muddier and more firmly packed substrates. My samples indicate that the recovery of shrimp populations was good, and clam spawn was found in samples taken directly from holes pumped 3 to 4 weeks before sampling. In fact, it appears that pumping operations actually enrich the mudflats by bringing rich organic deposits to the surface, thus making this material available to detritus feeders.

Very seldom do the bait pumpers get into clam beds, but it can occur. When this happens, the clams should be returned to the hole after the pump is removed. Otherwise, they are washed out over solid substrate, where they are unable to burrow before the heat of the sun kills them or they are picked up by gulls.

Conservation of the shrimp appears to be well exercised, since all soft-shelled and very small shrimp are not retained in the catch. The small shrimp readily burrow back beneath the surface. The pump in no way physically harms the mud dwellers, including the delicate ribbon worms, scaled worms, and commensal pea crabs. While ghost shrimp repopulate a pumped area within 3 to 4 weeks, about 6 months are required for the area to reach complete recovery and support profitable shrimp pumping. All regulations now governing the operations are biologically adequate; nevertheless, pumping should be restricted to daylight hours, since it involves equipment "capable" of digging clams. This restriction would affect the pumping very little, since low tides (which often occur during the night or early morning hours) are not necessary to operate the equipment. It also would alleviate the temptation to pump calms after dark. At the present, pumping is not restricted to daylight hours.

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REFERENCES

Aasen, Kenneth D. 1967. Summary of the 1963 and 1964 southern California inshore bait fishery. Calif. Fish and Game, 53 (1) : 28–34.

MacGinitie, G. E. 1934. The natural history of *Callianassa californiensis* Dana. Amer. Midland Natur., 15 (2) : 166–177.

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A SURVEY OF HELMINTH PARASITES IN THE SQUID, *LOLIGO OPALESCENS*, SMELT, *OSMERUS MORDAX*, JACK MACKEREL, *TRACHURUS SYMMETRICUS*, AND PACIFIC MACKEREL, *SCOMBER JAPONICUS*[1]

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One hundred and one specimens of squid, smelt, jack mackerel, and Pacific mackerel were examined for larval and adult helminth parasites. Infection rates were 8.0%, 76.9%, 84.0% and 92.0% in the smelt, squid, Pacific mackerel, and jack mackerel, respectively. Parasites recovered represented classes Cestoda, Trematoda, and Nematoda, and the phylum Acanthocephala.

INTRODUCTION

Cetacea and Pinnipedia with helminth parasites have been reported since before the turn of the century (Stiles and Hassall, 1899). However, there is a paucity of information concerning the biology and life histories of these parasites. It may be that captive animals are increasing their worm burdens through foods fed them. This study was conducted to determine the adult as well as the potential infective larval helminth stages in food fed to experimental marine mammals at the Point Mugu Marine Bioscience Facility.

MATERIALS AND METHODS

The squid, Pacific mackerel, and jack mackerel were obtained fresh from a major commercial seafood outlet. The smelt were taken from a frozen supply at Point Mugu. These supply sources are the same as those used by the Marine Bioscience Facility.

During necropsy the following areas were examined: mouth, gills, stomach, intestine, blood, heart, liver, air sacs, body cavity, mesenteries, bladder, eyes, and body tissue. All parasites found were prepared and mounted on slides for identification. Nematodes were killed in hot sea water and fixed in AFA (10 parts formalin, 50 parts 95% ETOH, 2 parts glacial acetic acid, and 40 parts distilled water). Trematodes, cestodes, and acanthocephalans were fixed in AFA, stained in Semichon's carmine or celestine blue B, dehydrated in ethanol, cleared in xylene, and mounted in Piccolyte. Mounted specimens were studied under both phase-contrast and ordinary light microscopes.

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RESULTS

Squid, *Loligo opalescens* Berry

Twenty-six animals, from five samples taken between November 1, 1967, and January 12, 1968, were examined. Of these, 20 (76.9%) were infected (Table 1).

TABLE 1

Incidence of Parasitism in Squid

Number examined	Number infected	Percentage infected	Organs infected	Parasites observed
26	20	76.9	Eye Stomach Caeca Body cavity Mesenteries	Cestoda Tetraphyllidea Pseudophyllidea Nematoda Philometroidea

Cestoda

Two types of juvenile cestodes were found. All were larvae in the plerocercoid stage of development belonging to the orders Tetraphyllidea and Pseudophyllidea.

The tetraphyllideans were identified as *Scolex pleuronectis bilocularis*, which has been reported previously from the cuttlefish, *Sepia officinalis* (Dollfus, 1964), and the jumbo squid, *Dosidicus gigas* (Fields, 1965). All adult members of the order Tetraphyllidea have been found exclusively in elasmobranch fishes.

Those larval stages belonging to the order Pseudophyllidea were identifiable only to ordinal level because of insufficient internal organ development. A more precise identification would require experimental infections of various hosts to recover the adult tapeworm. Members of this order in the genera *Diphyllobothrium*, *Diplogonoporus*, and *Pyramicocephalus* are known to infect marine mammals (Margolis, 1954).

Nematoda

Two nematodes were found in separate hosts. One damaged specimen taken from coelomic washings was identified as a larval member of the order Philometroidea. The adult members of this order are found in teleost fishes, particularly the flatfishes, and also in marine mammals. The other nematode was taken from the stomach and appeared to be a free living form that had been consumed during feeding.

Jack Mackerel, *Trachurus symmetricus* (Ayres)

Twenty-five jack mackerel were examined from six samples taken between November 28, 1967, and February 8, 1968. Of these, 23 (92.0%) were infected with helminth parasites (Table 2).

TABLE 2

Incidence of Parasitism in Jack Mackerel

Number examined	Number infected	Percentage infected	Organs infected	Parasites observed
25	23	92.0	Eye Stomach Caeca Body cavity Mesenteries Intestine Muscle	Cestoda Tetraphyllidea Trypanorhyncha Nematoda Ascaroidea Trematoda Hemiuridae Allocreadiidae Acanthocephala Neoechino-rhynchidea

Cestoda

Larval cestodes were found in 18 (72.0%) of the fish examined and were distributed throughout the fish's bodies. The heaviest infection was found in the abdominal wall muscle tissue. In over 50.0% of the fish examined, this tissue was pervaded with trypanorhynch plerocercus larvae which were identified as members of the genus *Dasyrhynchus*.

Two tetraphyllidean plerocercoid larvae, identified as *Scolex pleuronectis bilocularis* and *Scolex polymorphus unilocularis*, were found in the intestine, caeca, and body cavities.

Nematoda

Nematodes were found in 13 (52.0%) of the jack mackerel examined. Although these parasites were found in all parts of the body except the eye and muscle, they were most abundant as encysted forms in the mesenteries.

Contracaecum

Encysted *Contracaecum* larvae were found throughout the mesenteric fat surrounding the stomach in 11 of the 13 infected fish. The infection ranged from 2 to 11 larvae per host. *C. osculatum* has been reported from the stomachs of various pinnipeds: Steller sea lion (Stiles and Hassall, 1899), harbor seal (Fisher, 1952), California sea lion (Herman, 1942), and elephant seal (Caballero and Peregrina, 1938).

Porrocaecum

One larval *Porrocaecum* was found. This parasite was encysted in the wall of the stomach. Although adult members of the genus are commonly found in birds, few have been reported from the stomachs of pinnipeds and fissipeds. They are *Porrocaecum decipiens* in the northern fur seal (Stiles and Hassall, 1899), Steller sea lion (Scheffer and Slipp, 1944), harbor seal (Fisher, 1952) and sea otter (Rausch, 1953). *Porrocaecum* sp. was taken from the stomach of a California sea lion at the San Diego Zoo (Herman, 1942).

Anisakis

Two larval specimens of this genus were encysted in the body cavity of one jack mackerel and the stomach wall of another. As adult worms, members of this genus are primarily parasites of marine mammals and six species have been reported from both pinnipeds and cetaceans (Margolis, 1954).

Trematoda

Nine adult trematodes were taken from seven jack mackerel: six from stomachs, two from intestines, and one from the body cavity. Those found in stomachs and the body cavity were *Lecithochirium magnaporum*, while those from the intestines were *Opegaster* sp.

Acanthocephala

One adult specimen of this phylum was attached to the intestinal mucosa. It was a member of the order Echinorhynchidea, genus *Rhadinorhynchus*.

Pacific Mackerel, *Scomber japonicus* Houttouyn

Twenty-five Pacific mackerel were examined from five samples taken between December 28, 1967, and February 17, 1968. Twenty-one (84.0%) of the fish were infected (Table 3).

TABLE 3

Incidence of Parasitism in Pacific Mackerel

Number examined	Number infected	Percentage infected	Organs infected	Parasites observed
25	21	84.0	Stomach Caeca Body cavity Mesenterics Intestine	Cestoda Trypanorhyncha Pseudophyllidea Nematoda Ascaroidea Trematoda Hemiuridae

Cestoda

Larval cestodes were found in 15 (60.0%) of the fish examined and were representatives of the orders Trypanorhyncha and Pseudophyllidea. The typanorhynch plerocercus larvae were encysted in stomachs, intestines, caeca, abdominal cavities, and mesenteries. These larvae were of two types: one encapsulated in a large bladder-like cyst which measured 4 to 10 mm long by 3 mm wide; the other enclosed in a small teardrop-shaped cyst measuring only 1 mm in length and width. As mentioned previously, the adult members of this order are parasitic only in elasmobranch fishes. Only two plerocercoid larvae belonging to the order Pseudophyllidea were found encysted in the mesenteries of a single fish. These were identical to those found in the squid.

Nematoda

Nematodes were taken from 13 (42.0%) of the Pacific mackerel examined. The infection ranged from 1 to 46 larvae per fish, and larvae were found in all parts of the body.

Contracaecum

Twelve encysted larvae, *Contracaecum* sp., were found in the mesenteries of three fish. The infection was eight, three, and one larvae, respectively.

Porrocaecum

Four larval members of this genus were encysted in the intestinal wall and abdominal cavity of two fish.

Raphidascaris

A single immature specimen of this genus was taken from the mesenteric tissue surrounding the stomach. The adult members of this genus are parasitic only in fish.

Dujardinia

Two larval specimens of this genus were taken from the intestinal caeca of one fish. Parasites of this genus were found in the stomach of a captive California sea lion at the San Diego Zoo (Herman, 1942). Members of this genus are not widespread among pinnipeds and are unreported from cetaceans.

Anisakis

The most abundant nematodes in Pacific mackerel belong to this genus. They were found to infect all parts of the body and occurred in 13 (52.0%) of the fish examined. A total of 153 larval *Anisakis* was found in the 13 infected hosts. The infection per fish ranged from 1 to 46.

Trematoda

Three adult digentic trematodes were found in the intestines of two hosts. These were identified to the family Hemiuridae and are not known in marine mammals.

Smelt, *Osmerus mordax* (Mitchell)

Two (8.0%) of the 25 smelt examined were infected with adult acanthocephalans. These parasites belong to the family Echinorynchidea, genus *Echinorhynchus*. Members of this genus have been reported only from fishes and have no known infective potential for marine mammals.

DISCUSSION

There was a high incidence of infection in all hosts examined except the smelt. Squid harbored a preponderance of cestode larvae, particularly those belonging to the order Pseudophyllidea. The mackerels were heavily infected with cestode larvae, as well as with five species

of nematodes. This distribution of infection between hosts is probably due to several factors: the life history of the parasite, its size, and the feeding habits of the host animal.

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REFERENCES

Caballero, E., and D. I. Peregrina. 1938. Nematodes de los mamferos de Mexico. Ann. Inst. Biol. Mexico, 9: 289–306.

Dollfus, R. 1964. Enumeration de cestodes du plancton et des invertebres marins. Ann. de Parasitol. (Paris), 39: 329–379.

Fields, Gordon W. 1965. The structure, development, food relations, reproduction, and life history of the squid *Loligo opalescens* Berry. Calif. Dept. Fish and Game, Fish Bull. (131) : 1–108.

Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Bull. Fish. Res. Bd. Canada, (93) : 1–58.

Herman, C. M. 1942. The effect of higueronia on nematodes and nemathelminthic gastric ulcers of California sea lions. Rev. Med. Trop., Parasitol., Bact., Clinica y Lab., 8: 45–47.

Margolis, L. 1954. List of parasites recorded from sea mammals caught off the west coast of North America. Jour. Fish Res. Bd. Canada, 11 (3) : 267–283.

Rausch, R. 1953. Studies on the helminth fauna of Alaska. XIII. Disease in the sea otter, with special reference to helminth parasites. Ecology, 34: 584–604.

Scheffer, V. B., and J. W. Slipp. 1944. The harbour seal in Washington State. Amer. Midland Natur., 34: 373–416.

Stiles, C. W., and A. Hassall. 1899. Internal parasites of the fur seal: 99–177. *In* Jordan, D.S., Report of Fur Seal Investigations (1896–1897), Pt. 3: 1–629.

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OUTBREAK OF CRYPTOCARYONIASIS IN MARINE AQUARIA AT SCRIPPS INSTITUTION OF OCEANOGRAPHY[1]

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A histophagic ciliate, *Cryptocaryon irritans* Brown 1951, has been encountered in epizootic proportions in marine aquaria at Scripps Institution of Oceanography. The disease was controlled although not eliminated by copper sulphate treatments. A high concentration, short-term formalin-copper sulphate treatment was developed which did eliminate the disease from host fishes. The etiology of the disease is described and experiments with treatments are discussed.

The organism was found in one instance in a local population of tide pool fishes.

INTRODUCTION

In the summer of 1966, there was a severe mortality of marine fishes in both the public and experimental aquaria at the Scripps Institution of Oceanography. A large histophagic ciliate protozoan, *Cryptocaryon irritans* Brown, was thought to be the causal agent. This organism was first observed by Sikama (1938) in aquarium fishes from China. He recognized that it was similar to *Ichthyophthirius multifiliis* Fouquet, and later called it *I. marinus* (Sikama, 1961). Brown (1951) had found the parasite in imported fishes at the aquarium of the Zoological Society of London and described it as a new genus and species. She subsequently reported on its life history (Brown, 1963). Nigrelli and Ruggieri (1966) encountered the organism in the New York Aquarium, and stated that it may be widespread in marine aquaria throughout North America.

The life cycle of *Cryptocaryon* is relatively simple. The parasitic (feeding) stage, the trophont (Figure 1), ranges in size from 48 to 450 μ along the major axis. It lives primarily in and under the epithelial tissues of the skin, gills, eye, and buccal cavity, where it usually produces opaque white papules. When these burst the trophonts drop to the bottom, where they encyst (tomont stage). Within the cyst, the tomont multiplies and ultimately produces several thousand free-swimming tomites (similar to the trophont, but smaller, nonfeeding, and with longer cilia), which invade new hosts.

METHODS

Skin smears and gill sections were taken from both infected and noninfected fishes and examined by means of bright field and phase microscopy in wet, fast-green-stained and silver-impregnated preparations.

The effectiveness of ozone and copper sulphate solution in preventing infection of fish from encysted *Cryptocaryon* and the influence of

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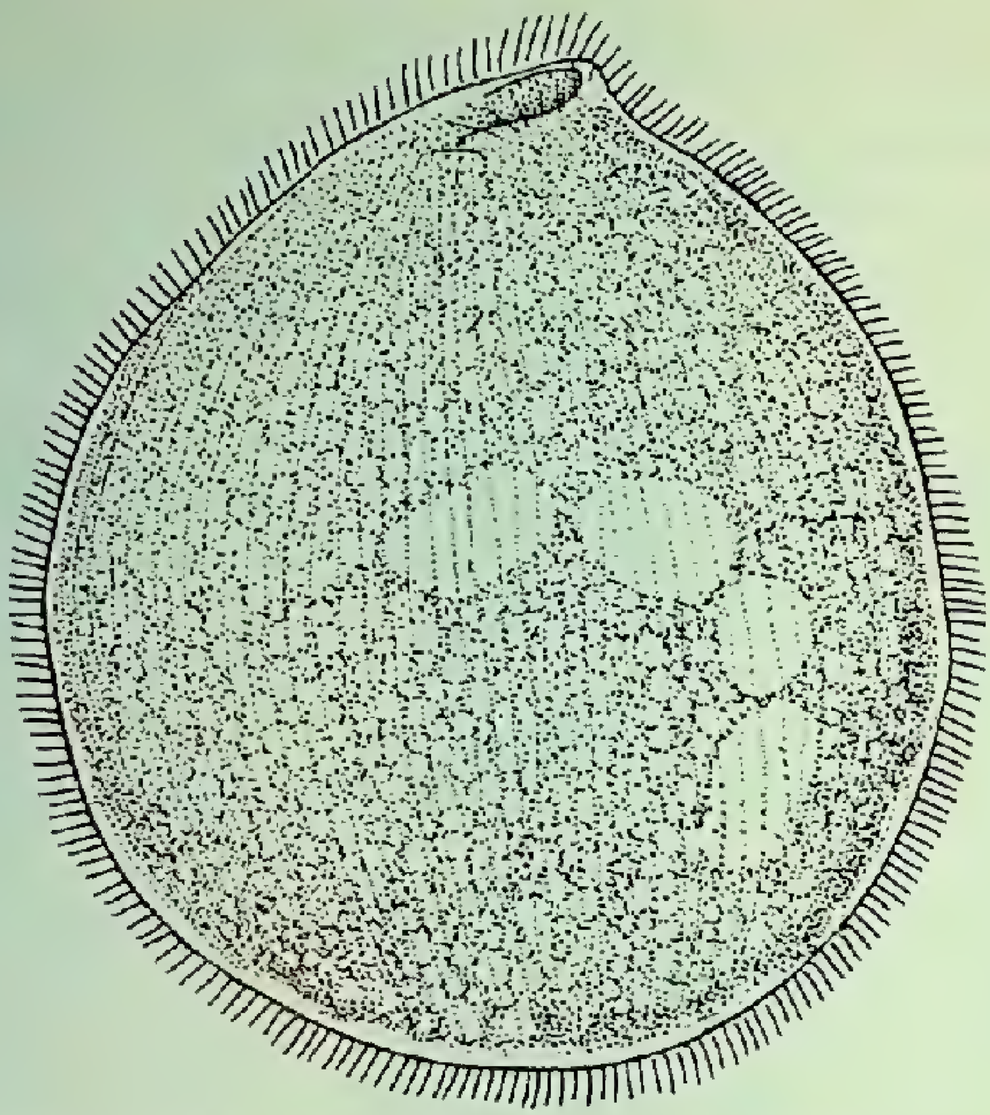

FIGURE 1—Trophont of *Cryptocaryon irritans* Brown as observed on fishes at Scripps Institution of Oceanography. About 350X.

temperature on infection were examined (Table 1). In each trial, 10 juvenile opaleye, *Girella nigricans*, were kept in a 15-gal aquarium containing a layer of sand taken from a diseased tank. In the ozone trial, ozone was supplied at a rate of 8 mg/hr by means of a Sander Type II ozonizer. The Cu level in the copper trial was maintained at 0.15 ppm as Cu. Both these experiments and the untreated control were main-

TABLE 1

The Effect of Temperature, Copper Sulphate, and Ozone on Encysted *Cryptocaryon irritans* Infecting Opaleye *Girella nigricans*.

Days exposed	Ozone 19.4 C	Cu^{++} 0.15 ppm 19.4 C	Ambient 19.4 C	Warm 23 C	Cold 14 C
1	A	A	A	A	A
7	A	A	A	P	A
15	A	A	P	P	A
21	A	A	P	P	A

A =Absent P = Present.

tained at 19.4 ($\pm$0.2) C. Two other untreated aquaria were maintained at 14 ($\pm$0.2) C, and 23 ($\pm$0.2) C, respectively. All trials were run simultaneously for a period of 22 days. It was not feasible to replicate the treatments.

Copper analyses were made with a Taylor Water Analyzer (1302) and copper slide (130 N). It was necessary to substitute ammonium citrate buffer for the ammonia solution provided by Taylor, because the latter was not suitable in seawater. This analysis is not as accurate as that described by Dempster (1955), but is adequate for controlling therapeutic levels. Ten analyses can be done in less than 30 min.

A number of other treatments were investigated, including Baslow solution (Nigrelli, 1966), chlorine dioxide, formalin, nitrofurazone, methylene blue, penicillin, quinine hydrochloride, and Trichofuron in therapeutic doses, which are normally utilized for treatment of fishes.

Following these trials, a high concentration short-term formalin-copper sulphate bath (shock treatment) was tested on several species of heavily infected fishes, primarily scorpaenids and serranids. The fishes were first placed for 30 min in a bath of 0.4 ml concentrated formalin (37%) per liter of aquarium water before copper sulphate solution was added to a concentration of 2.0 ppm as Cu. The seawater supply was then turned on at a rate which reduced the Cu level to 0.4 ppm over a period of 2 hours, with concommitant dilution of the formalin. Flushing continued until the aquarium was free of copper and formalin.

Smears taken from newly collected fishes found in tide pools along the La Jolla shore and from fishes caught in Mission Bay were examined for *Cryptocaryon* during the summers of 1966 and 1967.

OBSERVATIONS AND RESULTS

The diagnostic cytological characteristics, including general morphology, size, kinetosomes, buccal cavity structure, and the four-lobed meganucleus were identical to those described by Sikama (1938), Brown (1951), and Nigrelli and Ruggieri (1966). The lobed meganucleus was occasionally observable in wet mounts, as well as in stained preparations.

Cryptocaryon was first known to be present at Scripps when it attained epizootic proportions in August 1966 and the majority of aquarium fishes were afflicted. Aquarium water temperatures were above 20 C and had been since early July. If left untreated, even normally hardy species such as garibaldi, *Hypsypops rubicunda*, and opaleye died within a few days after white papules were visible macroscopically. For example, six seemingly healthy garibaldi living in 23-C water stopped eating, developed frosty corneas along with respiratory distress during the next 3 days, and by the end of 3 more days were dead. In most species of fishes, paling of the skin became noticeable after the loss of appetite, and before the clouding of the corneas. Within 2 to 3 days after paling, pinhead-sized white papules developed over most of the body and fins. After the first few days of infection, subsurface hemorrhaging usually became increasingly apparent, particularly in the fins. Respiration rates increased steadily during the last few days of the disease until death occurred. An additional symptom in yellowfin

croakers, *Umbrina roncador,* was the copious sloughing of integumental mucus in stringy masses. Postmortem microscopic examinations of gills, viscera, and blood revealed no other significant pathogens.

Fishes attacked by the disease included both tropical and temperate species (Table 2). The garibaldi was highly susceptible to the disease, apparently more so than any other species kept in the aquarium. No *Cryptocaryon* were found in smears from elasmobranchs or the gobiid

TABLE 2

Species Found Susceptible to *Cryptocaryon irritans* 1966–1967

ORDER SYNGNATHIFORMES
- Syngnathidae
  - *Syngnathus griseolineatus* Ayres

ORDER CYPRINODONTIFORMES
- Cyprinodontidae
  - *Fundulus parvipinnis* Girard

ORDER BERYCIFORMES
- Holocentridae
  - *Myripristis leiognathus* Valenciennes
  - *Holocentrus suborbitalis* (Gill)

ORDER MUGILIFORMES
- Mugilidae
  - *Mugil cephalus* Linnaeus
- Atherinidae
  - *Atherinops affinis* (Ayres)
  - *Atherinopsis californiensis* Girard
  - *Leuresthes tenuis* (Ayres)

ORDER PERCIFORMES
- Centropomidae
  - *Centropomus* sp.
- Serranidae
  - *Epinephelus analogus* Gill
  - *Epinephelus labriformis* (Jenyns)
  - *Alphestes galapagensis* Fowler
  - *Stereolepis gigas* Ayres
  - *Mycteroperca xenarcha* Jordan
  - *Paralabrax maculatofasciatus* (Steindachner)
  - *Paralabrax clathratus* (Girard)
  - *Paralabrax nebulifer* (Girard)
  - *Paranthias colonus* (Valenciennes)
  - *Roccus saxatilis* (Walbaum)
- Apogonidae
  - *Apogon retrosella* (Gill)
- Branchiostegidae
  - *Caulolatilus princeps* (Jenyns)
- Carangidae
  - *Seriola dorsalis* (Gill)
  - *Trachurus symmetricus* (Ayres)
  - *Selene* sp.
- Lutjanidae
  - *Lutjanus peru* (Nichols and Murphy)
  - *Lutjanus argentiventris* (Peters)
- Pomadasyidae
  - *Anisotremus davidsoni* (Steindachner)
  - *Anisotremus taeniatus* Gill

Sciaenidae
Cynoscion nobilis (Ayres)
Genyonemus lineatus (Ayres)
Roncador stearnsi (Steindachner)
Umbrina roncador Jordan and Gilbert
Scorpidae
Medialuna californiensis (Steindachner)
Kyphosidae
Kyphosus analogus (Gill)
Hermosilla azurea Jenkins and Evermann
Girellidae
Girella nigricans (Ayres)
Girella simplicidens Osburn and Nichols
Chaetodontidae
Heniochus nigrirostris (Gill)
Pomacanthus zonipectus (Gill)
Holacanthus passer Valenciennes
Embiotocidae
Amphistichus argenteus Agassiz
Amphistichus rhodoterus (Agassiz)
Brachyistius frenatus Gill
Cymatogaster aggregata Gibbons
Embiotoca jacksoni Agassiz
Hyperprosopon argenteum Gibbons
Hypsurus caryi (Agassiz)
Micrometrus minimus (Gibbons)
Phanerodon furcatus Girard
Rhacochilus toxotes Agassiz
Rhacochilus vacca (Girard)
Pomacentridae
Chromis punctipinnis (Cooper)
Hypsypops rubicunda (Girard)
Pomacentrus rectifraenum (Gill)
Abudefduf saxatilis (Linnaeus)
Microspathodon dorsalis (Gill)
Labridae
Bodianus diplotaenia (Gill)
Pimelometopon pulchrum (Ayres)
Halichoeres semicinctus (Ayres)
Thalassoma lucasanum (Gill)
Hemipteronotus pavoninus (Cuvier and Valenciennes)
Oxyjulis californica (Günther)
Cirrhitidae
Cirrhitus rivulatus (Valenciennes)
Cirrhitichthys oxycephalus
Blenniidae
Hypsoblennius gilberti (Jordan)
Hypsoblennius gentilis (Girard)
Clinidae
Starksia spinipenis (Hubbs)
Paraclinus integripinnis (Smith)
Labrisomus xanti Gill
Gibbonsia elegans (Cooper)
Heterostichus rostratus Girard
Acanthuridae
Prionurus punctatus Gill
Scombridae
Pneumatophorus japonicus (Houttuyn)
Stromateidae
Palometa simillima (Ayres)
Gobiidae
Coryphopterus nicholsi (Bean)

Scorpaenidae
Scorpaena guttata Girard
Sebastodes atrovirens (Jordan and Gilbert)
Sebastodes auriculatus (Girard)
Sebastodes carnatus (Jordan and Gilbert)
Sebastodes chrysomelas (Jordan and Gilbert)
Sebastodes constellatus (Jordan and Gilbert)
Sebastodes dalli (Eigenmann and Beeson)
Sebastodes miniatus (Jordan and Gilbert)
Sebastodes rosaceus Jordan and Gilbert
Sebastodes serriceps (Jordan and Gilbert)
Sebastodes umbrosus (Jordan and Gilbert)
Sebastodes vexillaris (Jordan and Gilbert)
Hexagrammidae
Oxylebius pictus Gill
Cottidae
Scorpaenichthys marmoratus (Ayres)
Clinocottus analis (Girard)
ORDER TETRADONTIFORMES
Canthigasteridae
Canthigaster punctatissima (Günther)
Diodontidae
Diodon holocanthus Linnaeus
ORDER LOPHIIFORMES
Antennariidae
Antennarius sanguineus Gill

Lythrypnus, and only an occasional one was found on muraenids, bothids, and pleuronectids. A number of species of aquarium fishes kept in the same tanks as diseased fishes did not exhibit macroscopic symptoms of the disease (Table 3).

The cold seawater tank (mean temperature 15 C) which contained primarily scorpaenids did not become infected, nor has there been an outbreak of *Cryptocaryon* in any of the untreated tanks during winter (temperature < 15 C). Throughout this period, however, the tropical tanks (20 to 26 C) have had to be treated regularly in order to control infection.

TABLE 3

Species Found Resistant to Cryptocaryoniasis

ORDER SQUALIFORMES
Heterodontidae
Heterodontus francisci (Girard)
Scyliorhinidae
Cephaloscyllium uter (Jordan and Gilbert)
Carcharinidae
Triakis semifasciata Girard
Squatinidae
Squatina californica Ayres
Rhinobatidae
Platyrhinoidis triseriata (Jordan and Gilbert)
Rhinobatis productus (Ayres)
Dasyatidae
Gymnura marmorata (Cooper)
Urolophus halleri Cooper
Myliobatidae
Myliobatis californicus Gill

ORDER ANGUILLIFORMES
  Muraenidae
    Gymnothorax mordax (Ayres)
    Echidna zebra (Shaw)
    Muraena lentiginosa Jenyns
ORDER PERCIFORMES
  Gobiidae
    Lythrypnus dalli (Gilbert)
    Lythrypnus zebra (Gilbert)
ORDER PLEURONECTIFORMES
  Bothidae
    Citharichthys sp.
    Paralichthys californicus (Ayres)
  Pleuronectidae
    Hypsopsetta guttulata (Girard)
    Platichthys stellatus (Pallas)
    Pleuronichthys coenosus Girard

TREATMENT

In 1966, as soon as a protozoan was implicated in the disease, all tanks suspected of being infected were treated with copper sulphate solution in a manner similar to that described by Dempster (1955), except that the ratio of citric acid and copper sulphate was changed from 1:100 to 1:5 to ensure the solubility of the copper sulphate. Treatments were daily in most aquaria throughout the summer and fall of 1966 and 1967, and have been sustained almost continuously since 1966 in the tropical tanks. Since the seawater system was open and chemical metering devices were not available, constant Cu levels could not be maintained. Twice a day the level was brought to 0.3 to 0.4 ppm as Cu. During the interim, additional copper sulphate solution was supplied by means of drip bottles to partially compensate for dilution. By this method the copper levels seldom dropped to lower than 0.15 ppm as Cu during the course of treatment.

Fishes treated with copper sulphate solution at 0.1 to 0.4 ppm Cu level were usually cured if treated during or before the early white-spot stage of the infection. Those that had reached more advanced stages almost invariably died. The disease had a tendency to reappear after termination of the treatment, particularly in warmer water aquaria. Furthermore, this treatment had no noticeable effect upon the trophont stage of *Cryptocaryon*. Smears from infected fishes treated at 0.4 ppm Cu level for 24 hours still contained an abundance of active trophonts.

In the experiment with encysted *Cryptocaryon*, no infection occurred during a period of 21 days in the aquaria containing ozone or copper sulphate or in the untreated 14-C tank. Infection occurred in the untreated 23-C tank after 7 days and after 14 days in the 19.4-C untreated tank.

The Baslow treatment was effective only in relation to the copper level it produced and maintained, and appeared no more effective than the copper treatment alone. It had no observable effect on attached trophonts.

The only treatment found to be more effective than the standard copper sulphate treatment was the formalin-copper sulphate shock

treatment. Fishes at the white-spot stage, treated in this manner, contained no visible *Cryptocaryon* in smears taken during the next 24 hours.

FIELD STUDIES

Since the summer of 1966, over 1,000 newly collected fishes from the La Jolla and Mission Bay areas have been examined. One mildly infected opaleye was found in a lot of 100 fishes of three species taken in tide pools 300 m north of Scripps pier.

Some *Cryptocaryon* also were found on an opaleye from a home aquarium equipped with all new materials and stocked with fish from tide pools 3 miles south of Scripps. Similar experiences have been reported by persons setting up aquaria at Scripps, but in these instances there was a possibility that the disease was introduced with the materials or sea water, and was not originally on the fish.

DISCUSSION

The source of the *Cryptocaryon* infection at Scripps is not known. If, as Sikama (1961) postulates, the disease is worldwide in distribution, it could have entered the aquarium from the local waters through the seawater supply. However, he reported the disease only from the water adjacent to Japan, and there is no previous record of its occurrence in eastern Pacific waters. The 1966 outbreak appears to be the first at Scripps, according to the aquarium records and the observations of Carr Tuthill (aquarium curator, Scripps Institution of Oceanography, pers. comm.) over the past 15 years. This suggests the previous absence of the organism in local waters.

On the other hand, Nigrelli and Ruggieri (1966) believe that this parasite has become established in North American aquaria through marine fishes imported from Hawaii and the Indo-Pacific area. It could have arrived at Scripps in this manner and subsequently could have been introduced into the local waters from the aquarium effluent. This also could have happened at the Sea World facilities, where the disease has been present (David Powell, curator, Sea World, San Diego, pers. comm.). The status of *Cryptocaryon* in local waters requires further investigation.

The pattern of susceptibility in western Pacific fish families observed by Sikama (1938) is similar to that at Scripps. It appears that elasmobranchs in general are little affected by *Cryptocaryon*. The resistant teleosts seem primarily to be those that live in contact with the substrate, and it may be that the mechanisms which protect them from abrasion injuries also provide a resistance to *Cryptocaryon*.

The standard copper sulphate treatment is effective, inasmuch as the fish recover if treated early enough. Since the effectiveness of copper solution on protozoans appears to be limited primarily to its lethal action on the free-swimming stages, a common aquarium practice is to maintain low levels of copper ion as a preventative measure. This may be undesirable, since it is believed that copper is a cumulative toxin and should not be used over long periods. Further, it is highly toxic

to invertebrates, so they cannot be displayed in the same tank with treated fishes.

The only treatment which we found effective against attached trophonts was the formalin-copper sulphate shock treatment. However, the initial Cu level is much above that considered safe by aquarists. We have experienced no mortality in conjunction with this treatment with scorpaenids and serranids, but have with embiotocids. This treatment, therefore, should be used with caution.

The tests of the majority of treatments were not as comprehensive as we would desire and were based on dosage levels recommended by van Duijn (1967) for freshwater fishes. It may be that some of these treatments might be of value at higher dosages or if administered in a different manner. For example, Raymond Benoit (Triton Aquatics, Inc., Levittown, Pa.) reports that ozone is effective if the temperature is raised above 30 C. This particular treatment has limited usefulness, since such a temperature would be lethal to many temperate species.

SUMMARY

Cryptocaryon irritans was identified as the causal organism in a severe disease outbreak in marine fishes maintained at the Scripps Institution of Oceanography in 1966.

The outbreak occurred during a period of increased water temperature. It did not affect fish kept in cold seawater (< 15 C).

Cryptocaryon was found on a newly caught local fish and on fish from an aquarium in which there was only a slight possibility of the organism being present before the introduction of local fish. This is the first known record of the organism in eastern Pacific waters. Since its occurrence could have resulted from aquarium effluent, further investigation of its status in local waters is indicated.

Low levels of copper sulphate solution, 0.1 to 0.4 ppm as Cu, were effective in preventing infection, but had little effect on the attached parasitic stage.

A formalin-copper sulphate shock treatment was effective against the parasitic stage and had no lethal effect on most host fishes tested.

ACKNOWLEDGMENTS

To all those who helped with treatments, observations, and collections we offer sincere gratitude, particularly Alexander Beamer, Charles Farwell, Katherine Hartwell, Monte Kirven, William Mautz, Daniel Popper, Patrick Smith, Robert Snodgrass, and Carr Tuthill. Raymond Benoit of Triton Aquatics, Inc., kindly supplied the ozonizer. Special thanks are owed to William Newman and Richard Rosenblatt, who read the manuscript and offered a number of helpful suggestions.

REFERENCES

Brown, E. M. 1951. A new parasitic protozoan the causal organism of a white spot disease in marine fish—*Cryptocaryon irritans* gen. & sp. n. Agenda Sci. Meet. Zool. Soc. London 1950, Agenda, (11) : 1–2.

———. 1963. Studies on *Cryptocaryon irritans*. Proc. 1st Int. Congr. Protozool. Prague 1961 : 284–287.

Dempster, R. P. 1955. The use of copper sulfate as a cure for fish diseases caused by parasitic dinoflagellates of the genus *Oodinium*. Zoologica, 40 (12) :133–138 + 1 plate.

Nigrelli, R. F., and G. D. Ruggieri. 1966. Enzootics in the New York Aquarium caused by *Cryptocaryon irritans* Brown, 1951 (= *Ichthyophthirius marinus* Sikama, 1961), a histophagous ciliate in the skin, eyes and gills of marine fishes. Zoologica, 51 (9) :97–102+7 plates.

Sikama, Y. 1938. Uber die Weisspunktchenkrankheit bei Seefischen. Jour. Shanghai Sci. Inst., Sec. 3, 4 : 113–128.

———. 1961. On a new species of *Ichthyophthirius* found in marine fishes. Sci. Rept., Yokosuka City Mus., (6) : 66–70.

van Duijn, C. 1967. Diseases of fishes. Iliffe Books, London. 309 p.

NOTES

DESERT BIGHORN *(OVIS CANADENSIS NELSONI)* LOSSES IN A NATURAL TRAP TANK

Bighorn in desert regions use natural tanks (tinajas) as a source of water. These tanks are carved out of rock by water action. They then collect and store runoff water which is used by wildlife.

On November 12, 1968, during investigations of sheep populations in Imperial County, California, a natural trap tank was discovered in a remote tributary of Julian Wash. This tank contained the remains of 34 bighorn sheep in various stages of decomposition (Figure 1). These

FIGURE 1—The natural tank trap as it appeared when discovered. It was 15 ft in diameter and 6 to 10 ft deep, with undercut sides. ***Photograph by the author, November 1968.***

remains were of 2 rams, 21 ewes, and 11 lambs. The deathtrap tank was less than 3 air miles from the Colorado River. It appears that the bighorns slipped into the tank in attempting to drink and were unable to gain footing to escape. Since it had been 2 years since the tank area was flushed out by storms, the losses are presumed to have occurred within this time period.

To prevent future losses, equipment was airlifted to the remote site and an escape ramp was constructed by California Department of Fish and Game crews. The ramp was made by carving a sloping side with rough steps on the lower side of the tank.—*Jerry L. Mensch, Wildlife Management Branch, California Department of Fish and Game.* *A contribution of Federal Aid to Wildlife Restoration Project W-52-R, "Big Game Investigations". Accepted March 1969.*

OCCURRENCE OF A PACIFIC RIDLEY AND A YOUNG NORTHERN FUR SEAL IN MONTEREY BAY

On November 8, 1967, I observed and photographed a Pacific ridley, *Lepidochelys olivacea*, from the pier adjacent to the Monterey Bay breakwater off Cannery Row, Monterey, California. The turtle was first observed while students from the Moss Landing Marine Laboratories, in cooperation with Daniel J. Miller, Marine Biologist, California Department of Fish and Game, were lowering fish traps from the pier.

The turtle was about 3 ft below the surface, swimming under and parallel to the pier. It swam slowly and turned in several directions, moving its head from side to side as it carefully looked over the encrusting marine life covering the large rocks of the breakwater. Occasionally it swam into water about 9 to 12 ft deep, but soon rose again near to the surface. I observed it for about 3 min while it swam leisurely three-fourths the length of the pier and then turned and doubled on its path. As the turtle turned, it swam back into full sun about 6 inches below the surface and I was able to photograph it (Figure 1). A student, Garvin Hoefler, also took motion pictures which clearly revealed two claws on each foreflipper. The green turtle, *Chelonia mydas*, for which the ridley could easily be mistaken, has been reported from California waters, but it has only one claw on each foreflipper. The color pattern of the carapace as well was typical of the ridley. A com-

FIGURE 1—Pacific ridley swimming between pier pilings of the Monterey breakwater, Monterey Bay, California.

parison with the width of an adjacent wharf timber indicated that the turtle had a carapace length of approximately 80 cm.

Northern wandering of the Pacific ridley was first recorded by Houck and Joseph (1958), who reported an individual taken at Table Bluff, near Eureka, Humboldt County, California. The usual range of distribution of this species is considered to be tropical and subtropical (Carr, 1952; Stebbins, 1966).

On November 28, 1967, a pup northern fur seal, *Callorhinus ursinus,* hauled out on Sunset Beach about 2 miles north of Moss Landing, Monterey Bay, California (Figure 2). It was discovered and captured by students of the Monterey Bay Academy. The animal was in very poor condition and possessed a nervous tic. It was kept at the San Jose Zoo for a week and then died. The day after they captured this pup, the

FIGURE 2—Young northern fur seal after its capture at Sunset Beach, Monterey Bay, California. *Photograph by Ralph R. Swenson.*

students returned to the same area and discovered another pup on the beach. However, this animal escaped into the ocean.

Annual southward migrations of northern fur seals from their breeding grounds in the Pribilof Islands of Alaska have been amply documented (Kenyon and Wilke, 1953; Taylor, Fujinaga, and Wilke, 1955). The fur seal is largely pelagic most of the year and can be found 10 to 80 miles off the California coast during the months of January to April. Recent observations (published and unpublished) verify the occasional occurrence of adult northern fur seals on or near offshore islands (Orr and Poulter, 1965; Richard S. Peterson, University of California, Santa Cruz, pers. comm.).

In the first winter of southward migration, pup fur seals are rarely known to travel south of northern Oregon, and only under exceptional circumstances, such as severe winter storms and low temperatures, have they been reported to haul out on land (Scheffer, 1950). The pups born in July depart from the Pribilof Island rookeries in November (Kenyon and Wilke, 1953; Taylor, Fujinaga, and Wilke, 1955). Arrival in Monterey Bay on November 28 is a remarkably short time to travel the estimated 2,515 miles from the Pribilofs. A fur seal colony has recently been reported on San Miguel Island (Peterson, Le Boeuf, and Delong, 1968), so the pups may have originated there.

The pup, a female, weighed 5.18 kg and has been deposited in the mammal collection of the Museum of Vertebrate Zoology, San Jose State College, San Jose, California (MVZ No. 2315). Unfortunately, an autopsy was not performed on this animal to determine the level of parasitism or to reveal any internal injuries. Comparison of the skull, dentition, and pelt of this animal with specimens of similar size donated by the Biological Sonar Laboratories, Stanford Research Institute, with the specimens in the collection of the California Academy of Sciences, and with the collection at the U.S. Bureau of Commercial Fisheries, Marine Mammal Biological Laboratory in Seattle, Washington, verifies the age of the pup as 3 to 5 months.

I am grateful to Archie Carr of the University of Florida, Gainesville, for verification of identity of the turtle; to Victor B. Scheffer and Clifford Fiscus of the Marine Mammal Biological Laboratory, Seattle, who confirmed the age of the fur seal pup by examination of the canine teeth; and to Ralph R. Swenson of the Monterey Bay Academy, who provided details of capture and the photograph of the fur seal.

REFERENCES

Carr, Archie. 1952. Handbook of turtles. Cornell Univ. Press, Ithaca, New York. 542 p.

Houck, Warren J., and James G. Joseph. 1958. A northern record for the Pacific ridley, *Lepidochelys olivacea*. Copeia, 1958 (3) : 219–220.

Kenyon, Karl W., and Ford Wilke. 1953. Migration of the northern fur seal, *Callorhinus ursinus*. Jour. Mammal, 34 (1) : 86–98.

Orr, Robert T., and Thomas C. Poulter. 1965. The pinniped population of Ano Nuevo Island, California. Proc. Calif. Acad. Sci., 32 (13) : 377–404.

Peterson, Richard S., Burney J. Le Boeuf, and Robert L. Delong. 1968. Fur seals from the Bering Sea breeding in California. Nature, 219 (5157) : 899–901.

Scheffer, Victor B. 1950. Winter injury to young fur seals on the northwest coast. Calif. Fish and Game, 36 (4) : 378–379.

Stebbins, Robert C. 1966. A field guide to western reptiles and amphibians. Houghton Mifflin Co., Boston. xvi + 279 p.

Taylor, F. H. C., M. Fujinaga, and Ford Wilke. 1955. Distribution and food habits of the fur seals of the North Pacific Ocean. U.S. Fish Wildl. Serv. 86 p.

G. Victor Morejohn, Moss Landing Marine Laboratories, Moss Landing, California 95039. *Accepted December 1968.*

THE ADDITION OF THE MIRROR DORY, *ZENOPSIS NEBULOSA* (TEMMINCK AND SCHLEGEL), TO THE CALIFORNIAN FAUNA

The recorded range of the mirror dory, *Zenopsis nebulosa,* is from Japan to Australia in the western Pacific, and it has been recorded from New Zealand, Korea, and Hawaii (Tomiyama and Abe, 1958). This species has been taken in trawls as deep as 70 fathoms off Australia (Munro, 1957) and in gill nets at about 15 fathoms in Japan (Ueno and Abe, 1966). However, this is the first report of the mirror dory in the eastern Pacific.

In July 1961, Peter Burton, Captain of the trawler *Franklin,* caught a 425-mm TL male specimen in 80 to 85 fathoms, lat 34° 54′ N, long 120° 50′ W, 7 miles west of Point Sal, Santa Barbara County. The fish is now in the collection of California Polytechnic College in San Luis Obispo (F6805091). A second specimen, a female 480 mm TL, was taken in February 1966 by Thomas Webster, current Captain of the same trawler. It was taken in 80 or 120 fathoms at the eastern end of the Santa Barbara Channel, lat 34° 4′ N, long 119° 20′ W. This fish is in

FIGURE 1—A mirror dory, *Zenopsis nebulosa*, 506 mm TL; taken in Monterey Bay, June 6, 1967.

the California Academy of Sciences collection (C.A.S. 23897). A third mirror dory, a 506-mm TL female (Figure 1), was taken in Monterey Bay by Natale Caronia, Captain of the trawler *Anthony Boy*, on June 6, 1967, in 34 fathoms, southwest of Santa Cruz, lat 36° 53′ N, long 122° 3′ W. This fish is also in the California Academy of Sciences collection (C.A.S. 24164).

The meristic counts of the three specimens (Table 1) agree with the original description but disagree with subsequent reports on the number of buckler scales anterior to the pelvic fins. Temminck and Schlegel (1842) report the presence of six of these scales but state that the form and number may vary. Okada (1955) and Jordan and Fowler (1902) report three scales, while Munro (1957) finds two or three.

Tomiyama and Abe (1958) state that the spawning time in Japan is January and February. The ova of the February 1966 specimen were minute, while those of the June 1967 specimen were moderately

TABLE 1

Counts and Measurements of California *Zenopsis nebulosa*

Counts	1961 Cal. Poly. F6805091	1966 C.A.S. 23897	1967 C.A.S. 24164
Dorsal fin	IX,27	IX,27	IX,26
Caudal fin	i,5,6,i	i,5,6,i	i,5,6,i
Anal fin	III,26	III,26	III,26
Pectoral fins	12	13	12
Pelvic fins	I,5	I,5	I,5
Gill rakers on first arch	3/15	3/18	3/16
Pored tubes in lateral line	76+4	91+4	71+4
Dorsal bucklers	14	14	15
Anal bucklers	7	7	8
Abdominal bucklers	8	8	8
Jugular bucklers (pairs + median)	2+4	3+3	3+3

Measurements	mm	Per mille standard length	mm	Per mille standard length	mm	Per mille standard length
Total length	425	1214	480	1230	506	1265
Standard length	350	1000	390	1000	400	1000
Greatest body depth	181	517	207	530	211	527
Depth of caudal peduncle	17	48	20	51	21	52
Head length	129	368	151	387	138	345
Diameter of bony orbit	31	88	33	84	31	77
Interorbital width	25	71	29	74	29	72
Snout length	60	171	72	184	65	162
Length of upper jaw	60	171	68	174	67	167
Snout to dorsal origin	132	377	146	374	140	350
Base of dorsal	218	622	232	594	250	625
Length of 1st dorsal spine	53*	151	95*	243	114*	285
Length of longest soft dorsal rays	41	117	49	125	40	100
Snout to anal origin	221	631	265	679	258	645
Base of anal	156	445	174	446	184	460
Length of longest soft anal rays	46	131	47	120	41	102
Length of pelvic spine	63*	180	105	269	81*	202
Length of pectoral fin	56	160	60	155	60	150

* Broken.

developed. The 1966 specimen had the remains of a shortbelly rockfish, *Sebastodes jordani*, about 200 mm long in its stomach, but the stomachs of the 1961 and 1967 specimens were empty. The otoliths (sagittae) of the 1966 specimen appear to have seven winter zones. Because of the small size of the sagittae (2.1 mm in the 1966 fish) and the length of time in preservative I was unable to recover the otoliths from the other fish. The skin color of these specimens when freshly frozen was silver-gray with blue-black counter-shading, and the fins were blue-black.

ACKNOWLEDGMENTS

I would like to express my thanks to John Applegarth and Harry Fierstine of California Polytechnic College for the use of the 1961 fish and to Lillian Dempster and William I. Follett, California Academy of Sciences, for providing literature on *Zenopsis*. John E. Fitch, California Department of Fish and Game, gave much assistance, particularly with the otoliths.

REFERENCES

Jordan, D. S., and Henry W. Fowler. 1902. A review of the Chaetodontidae and related families of fishes found in the waters of Japan. Proc. U. S. Natl. Mus., 25 : 513–563.

Munro, Ian S. R. 1957. Handbook of Australian fishes. Australian Fish. Newsletter, 16 (12) : 17–20.

Okada, Yaichiro. 1955. Fishes of Japan. Maruzen Co., Tokyo. 434 p.

Temminck, Coenraad Jacob, and Hermann Schlegel. 1842–1850. Pisces. *In* Philipp Franz von Siebold, Fauna Japonica. Leyden. 324 p.

Tomiyama, I., and T. Abe. 1958. Encyclopedia zoologica illustrated in colours. Vol. 2. Hokuryu-Kan Co., Tokyo. 329 p.

Ueno, Tatsuji, and Koji Abe. 1966. On rare or newly found fishes from the water of Hokkaido (I). Jap. Jour. Ichthyol., 13 (4/6) : 220–228.

—*Paul Gregory, Marine Resources Operations, California Department of Fish and Game.* *Accepted December 1968.*

NORTHERN RANGE EXTENSION FOR *PARALEPIS ATLANTICA* KROYER IN THE EASTERN NORTH PACIFIC

The vertebral remains of *Paralepis atlantica* Kroyer (*Magnisudis barysoma* Harry) found in the stomach of a northern fur seal, *Callorhinus ursinus*, taken April 14, 1959, approximately 38 miles west of Willapa Bay, Washington (lat 46° 35′ N, long 124° 58′ W) represent a new northern record for this fish in the eastern Pacific Ocean.

The stomachs of 10,570 northern fur seals, collected in the eastern Pacific Ocean from 1958 to 1967, have been examined during pelagic fur seal research conducted by the Bureau of Commercial Fisheries, Marine Mammal Biological Laboratory, Seattle, Washington. Eighteen of these stomachs contained remains of one or more *P. atlantica* (Table 1). Measurements and meristic counts were made whenever possible (Table 2).

TABLE 1

Occurrence of *Paralepis atlantica* off California and Washington

Date of collection	Field number	Location*		Depth at collection area (fathoms)	Number of *P. atlantica* in stomach	Remarks
		Lat N	Long W			
1958†						
Mar. 13	1749	37°30′	124°00′	1,950	1	Vertebrae‡
1959†						
Feb. 20	904	34°32′	121°57′	2,100	1	Vertebrae
Mar. 18	1033	41°51′	125°18′	1,700	6	Parts of 6 fish
Mar. 20	1056	41°05′	125°38′	1,690	6	One complete fish and parts of 5
Mar. 27	1095§	40°25′	125°11′	1,300	5	Four complete fish and part of 1
Mar. 28	1101	41°02′	125°21′	1,660	2	Vertebrae and remains
Apr. 1	1109	41°09′	124°53′	1,000	1	Vertebrae
Apr. 1	1115	41°17′	124°56′	890	9	Two complete fish and parts of 7
Apr. 1	1118	41°27′	124°58′	740	1	Vertebrae and remains
Apr. 4	1126	41°02′	125°08′	1,650	3	Vertebrae and remains
Apr. 4	1128	41°02′	125°08′	1,650	9	One complete fish and parts of 8
Apr. 4	1129	41°01′	125°08′	1,650	12	Vertebrae and fins of 12 fish
Apr. 4	1130	41°01′	125°08′	1,650	2	Vertebrae and remains
Apr. 5	1135	41°01′	124°52′	909	1	Vertebrae and remains
Apr. 14	1184	46°35′	124°58′	600	1	Vertebrae
1964						
May 28	335	40°57′	124°46′	500	1	Vertebrae
1966						
Feb. 17	412	36°24′	123°19′	1,800	1	Vertebrae
Mar. 6	253	35°51′	122°07′	600	2	Two nearly complete fish.

* Locations where fur seals containing *P. atlantica* were collected.
† Data on specimens taken in 1958 and 1959 were contributed by C. H. Fiscus, Bureau of Commercial Fisheries, Marine Mammal Biological Laboratory, Seattle, Wash.
‡ Identified in 1959 when comparative material became available.
§ Identified by A. D. Welander, College of Fisheries, University of Washington, Seattle, Wash.

TABLE 2

Counts From Specimens of *Paralepis atlantica*

Item	Count	Number of fish
Dorsal fin rays	10	5
	11	1
Anal fin rays	22	2
	23	2
Pectoral fin rays	15	2
	16	3
	17	2
Pelvic fin rays	9	4
Gill rakers	9+29	1
	9+32	1
Total vertebrae	67	3
	68	3
	69	3

P. atlantica has a cosmopolitan distribution, and otoliths in stomachs of bigeye tuna, *Thunnus obesus*, and albacore, *T. alalunga*, indicate that these fish are probably fairly common in California waters. In 1967, William Craig, California Department of Fish and Game, collected otoliths from the stomachs of several bigeye tuna taken in California waters. John Fitch, California Department of Fish and Game, provided the following data to Robert Rofen in 1960: "3 specimens brought in by R. G. Hamilton. Spit up by albacore caught between September 14 and 18, 1957, some 70 miles S.W. of Morro Bay . . . . Mr. Hamilton reported seeing a school of 100 to 200 *Magnisudis* being chased across the surface of the water beside his boat by albacore at this locality. One other fisherman reported a similar occurrence involving fewer *Magnisudis* but at the same general time and in the same general area" (Herbert Frey, California Department of Fish and Game, pers. comm.). Ronald R. McConnaughey and party took a live *Magnisudis* by hand in surf in a few ft of water over sand bottom at La Jolla Bay, San Diego County, California, January 15, 1955 (Richard Rosenblatt, Scripps Institution of Oceanography, pers. comm.).

REFERENCES

Harry, Robert R.

1953*a*. Studies on the bathypelagic fishes of the family Paralepididae. 1. Survey of the genera. Pac. Sci. 7 (2) : 219–249.

1953*b*. Studies on the bathypelagic fishes of the family Paralepididae. (Order Iniomi). 2. A revision of the North Pacific species. Proc. Acad. Nat. Sci. Phila., 105 : 169–230.

Rofen, Robert R.

1966. Family Paralepididae, Barricudinas, p. 205–459. *In* Fishes of the western North Atlantic. Mem. Sears Found. Mar. Res. (1), pt. 5.

—Hiroshi Kajimura, Marine Mammal Biological Laboratory, Bureau of Commercial Fisheries, Seattle, Washington 98115. *Accepted December 1968.*

A LARVAL CESTODE FROM THE PISMO CLAM, *TIVELA STULTORUM*[1]

Pismo clams, *Tivela stultorum*, collected from the ocean beach near Watsonville, California, were found to be parasitized by larval cestodes. The infestation was first noted while examining histological preparations of these clams. Cysts were subsequently teased from clams which had been frozen while the histological sections were being prepared.

Infestations of clams and oysters by cestode larvae have been reported by MacGinitie and MacGinitie (1949); Sparks (1963); Cheng (1966); Sparks and Chew (1966); Cheng (1967); Katkansky and Warner (1969); and Warner and Katkansky (1969).

Cysts were dissected from the clam tissue; the larvae were excysted and then photographed, using a Zeiss photomicroscope. For histological examination, a section of the foot of the clam was fixed in Davidson's

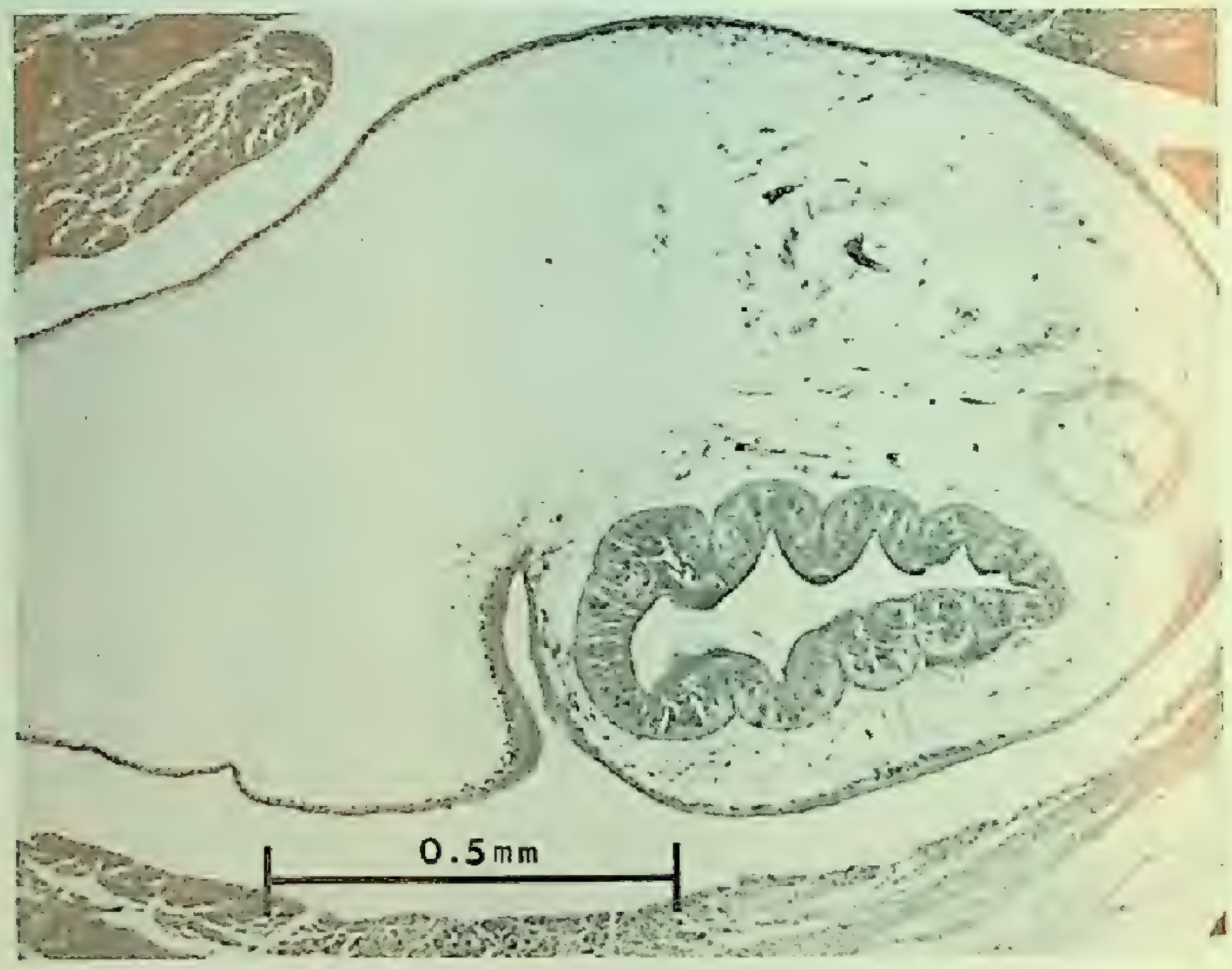

FIGURE 1—A single encysted larval cestode.

solution, processed using standard histological techniques, and stained with hematoxylin and eosin.

Large, yellowish-white cysts measuring 3.2 to 3.8 mm in diameter, located in connective and gonadal tissue adjacent to the intestine (Fig-

[1] This study was made as part of investigations under research contract No. 14-17-0001-1509 with the Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service.

ure 1), were taken from a number of clams. Very few cysts were found in each infested clam and they were extremely inconspicuous, being nearly identical in color to the surrounding tissue. A single plerocercoid larva, tentatively identified as *Echeneibothrium myzorhynchum*, was observed in each cyst. The larvae measured 3.4 to 4.2 mm in length (rostellum everted) and possessed four oval bothridia measuring 1.6 to 1.8 mm in length and 0.8 to 1.0 mm in width. A domelike rostellum or myzorhynchus was present and contained an internal muscular mass ranging from 0.5 to 0.65 mm in length (everted) and 0.40 to 0.45 mm in width which, in freshly thawed material, partially projected through the terminal opening (Figure 2). The adherent surface of each bothridium was subdivided into 10 loculi by 1 longitudinal and 9 transverse ridges (Figure 3).

The bothridia of the cestodes in Pismo clams are identical to those described in *E. myzorhynchum* by Wardle and McLeod (1952). Hart (1936) indicates that the abothrial surfaces of *E. myzorhynchum* were covered with small hooks and each bothridium was no longer than 0.6 mm. We observed no hooks and the bothridia of the cestodes in Pismo clams were up to three times as long as those mentioned by Hart.

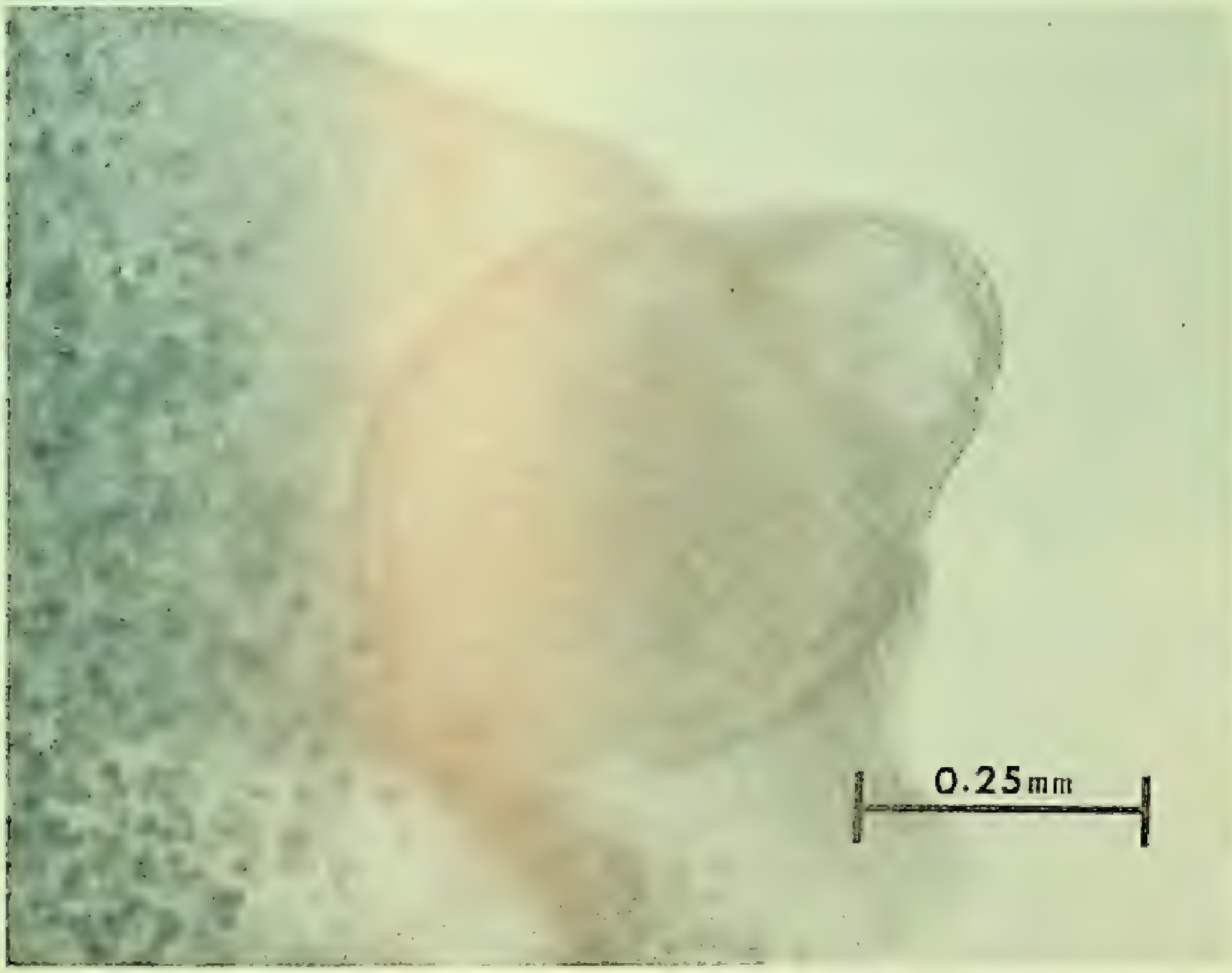

FIGURE 2—Everted rostellum of plerocercoid larva.

Wardle and McLeod (1952) state that the rostellum of *E. myzorhynchum* is cylindrical. The rostellum of the cestodes in Pismo clams more closely resembles that of *E. fallax* as described by Wardle and McLeod in that it is domelike, with a terminal opening, over a nearly circular internal muscular mass. The descriptions of the cestodes by Wardle and McLeod and Hart are of adults and the discrepancies noted in the plerocercoids may be due to development which may occur in the definitive host. Hyman (1951) gives some support to this speculation in a

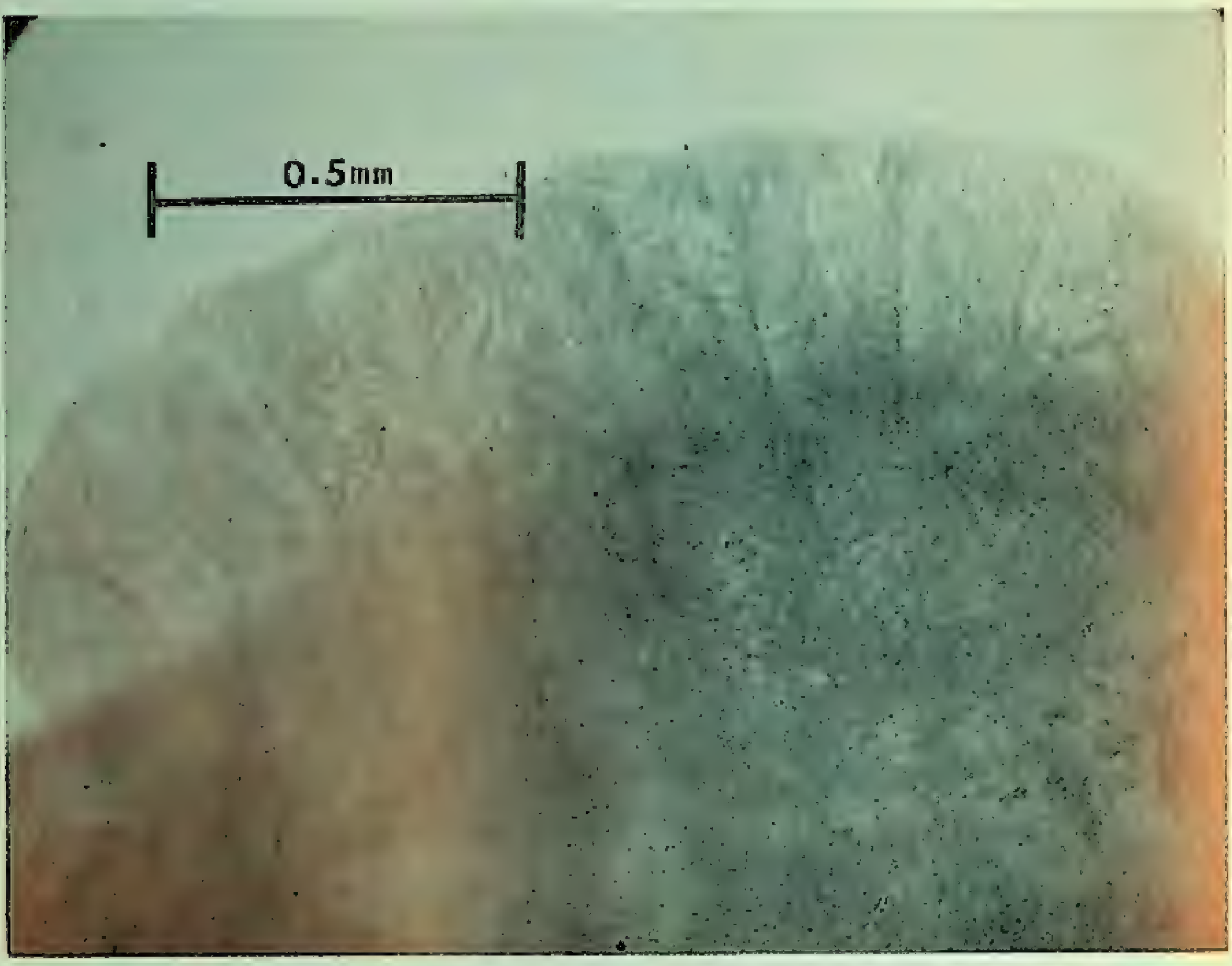

FIGURE 3—Detail of bothridium of plerocercoid larva.

brief description of *Echeneibothrium*: " . . . with a myzorhynchus at least in young stages".

Colorless cysts supposedly containing trematodes or flukes have been observed in Pismo clams by Fitch (1961). The inhabitants of these cysts were identified by other workers and their identification is probably erroneous (J. E. Fitch, Calif. Dept. Fish and Game, pers. comm.). Thus, the parasite we are describing is in all probability identical to the one discussed by Fitch.

Elasmobranchs are noted predators of bivalves. Most Pismo clams are seldom found deeper than 6 inches in the substratum (Fitch, 1953), making them susceptible prey. Babel (1967) reported Pismo clam remains in stomach contents of the round stingray, *Urolophus halleri*. Parasitological examination by Riser (1949) of 73 big skates, *Raja binoculata*, from Monterey Bay revealed the majority to be infested by adult *E. myzorhynchum*. It is possible that the big skate serves as the

definitive host for the plerocercoids found in Pismo clams. Although there are some inconsistencies in morphological characteristics with those described by previous authors, we tentatively identify the larval cestode in question as *E. myzorhynchum*.

REFERENCES

Babel, J. S. 1967. Reproduction, life history, and ecology of the round stingray, *Urolophus halleri* (Cooper). Calif. Dept. Fish and Game, Fish Bull., (137): 1–104.

Cheng, T. C. 1966. The coracidium of the cestode *Tylocephalum* and the migration and fate of this parasite in the American oyster, *Crassostrea virginica*. Trans. Amer. Microscop. Soc., 85: 246–255.

———. 1967. Marine molluscs as hosts for symbioses (Advances in marine biology, Vol. 5.) Academic Press, London and New York. 422 p.

Fitch, J. E. 1953. Common marine bivalves of California. Calif. Dept. of Fish and Game, Fish Bull., (90): 1–102.

———. 1961. The Pismo clam. Calif. Dept. Fish and Game, Marine Resources Leaflet (1): 1–22.

Hart, J. F. 1936. Cestoda from fishes of Puget Sound. 3. Phyllobothroidea. Trans. Amer. Microscop. Soc., 55: 488–496.

Hyman, L. H. 1951. The invertebrates: Platyhelminthes and Rhynchocoela. McGraw-Hill Book Co., New York. 550 p.

Katkansky, S. C., and R. W. Warner. 1969. Infestation of the rough-sided littleneck clam, *Protothaca laciniata*, in Morro Bay, California, with larval cestodes (*Echeneibothrium* sp.). Jour. Invert. Pathol., 13(1): 125–128.

MacGinitie, G. E., and N. MacGinitie. 1949. Natural history of marine animals. McGraw-Hill Book Co., New York. 473 p.

Riser, N. W. 1949. Studies on the Tetraphyllidia. Stanford Univ., Ph.D. Dissertation. 159 p.

Sparks, A. K. 1963. Infection of *Crassostrea virginica* (Gmelin) from Hawaii with a larval tapeworm, *Tylocephalum*. Jour. Insect Pathol., 5: 284–288.

Sparks, A. K., and K. K. Chew. 1966. Gross infestation of the littleneck clam (*Venerupis staminea*) with a larval cestode (*Echeneibothrium* sp.). Jour. Invert. Pathol., 8: 413–416.

Wardle, R. A., and J. A. McLeod. 1952. The zoology of tapeworms. Univ. of Minnesota Press, Minneapolis. 780 p.

Warner, R. W., and S. C. Katkansky. 1969. Infestation of the clam *Protothaca staminea* by two species of tetraphyllidian cestodes (*Echeneibothrium* spp.). Jour. Invert. Pathol., 13(1): 129–133.

—*Ronald W. Warner and Stanley C. Katkansky, Marine Resources Operations, California Department of Fish and Game.* *Accepted March 1969.*

PALAEMONETES PALUDOSUS COLLECTED IN THE RIO HARDY AND COLORADO RIVER, BAJA CALIFORNIA

The authors collected freshwater shrimp, *Palaemonetes paludosus*, in the Rio Hardy near its confluence with the Colorado River and in the combined flows of the Rio Hardy and the Colorado River. Tentative identification was confirmed by Allyn G. Smith, California Academy of Sciences, and Tom Cukr, Scripps Institution of Oceanography.

Shrimp were collected in large numbers in the Rio Hardy 42 miles south of Mexicali, at Del Prado Camp, on March 11, 1968; in the combined flow of the Rio Hardy and the Colorado River 60 miles south of Mexicali, at Vuelta La Corvina Camp, on March 11 and May 6, 1968; and in the combined flow of the Rio Hardy and the Colorado River 70 to 80 miles south of Mexicali, at Las Panzas Camp, on March 11 and June 3, 1968.

In all three areas *P. paludosus* was collected in waters inhabited by marine shrimps and fishes. A water sample at Vuelta La Corvina yielded a specific gravity reading of 1.020 at 23 C.

Adult males, females carrying eggs, and juveniles were collected. Several successive spawnings were observed in freshwater aquaria at Chino Fish and Wildlife Base. These spawnings occurred over a period of several months.

P. paludosus was introduced into the lower Colorado River, California, by the California Department of Fish and Game in 1958. Approximately 225 individuals were planted in a pond contiguous to Lake Havasu and 1,000 in three ponds in the Imperial National Wildlife Refuge (Hayden, 1963). It is now established but not abundant in certain areas of the Colorado River north of the Mexican border to Davis Dam.

South of the border, we readily collected large numbers of this shrimp with a dip net in the Rio Hardy and the Colorado River in all areas where suitable cover, principally sago pondweed (*Potamogeton pectinatus*), was present. We conclude that *P. paludosus* is well established in these areas.

REFERENCE

Hayden, Robert P. 1963. Introduction of *Palaemonetes paludosus*, a freshwater shrimp, into the lower Colorado River. Calif. Fish and Game, 49 (4) : 304–306.

—*James A. St. Amant and Robert G. Hulquist, Inland Fisheries, Region 5, California Department of Fish and Game.* *Accepted March 1969.*

BOOK REVIEWS

Fisheries Biology: A Study in Population Dynamics

By D. H. Cushing; The University of Wisconsin Press, Madison, 1968; xii + 200 p., illustrated. $7.50.

This book was developed from a series of university lectures. It covers a wide range of subjects including migrations, stock composition, measurements of abundance and mortality rates, growth, and stock and recruitment. The text is based principally upon research work on fisheries in the North Sea and adjacent areas, although some results from other areas are included.

I believe that the book is valuable primarily as a summary of some of the excellent fisheries investigations in the North Sea and as an exposition of some of the author's ideas. The author's approach to some subjects is refreshing. Growth, for example, is considered from the standpoint of the ecological significance of growth characteristics.

I do not believe that the book will be particularly useful as a general fisheries text, as could be implied from the title and introduction. My primary reason for this belief is the incomplete coverage of some subjects. For example, estimation of abundance is considered only from the standpoint of using catch per unit of effort as an index of stock size. Mark and recapture techniques are considered later in connection with estimating mortality rates, but they are treated incompletely since the stochastic models developed by Jolly and others are not discussed. Basically this incompleteness reflects an attempt to cover too broad a scope in too little space.

A second deficiency is that the text is sometimes difficult to follow because of one or another shortcomings in writing. For example, the text is not explicit enough in several places. In particular, I found the sections on availability and catchability confusing because of a failure to define precisely the terms catchability, vulnerability, accessibility, and availability. In places, I also had trouble following the text because geographical locations were not identified adequately in the figures.—*Harold K. Chadwick.*

The Hunter's Bible

By W. K. Merrill; Doubleday and Company, Inc., New York, 1968; 182 p., illustrated. $1.95 paper.

In this paperback book, the author has attempted, and with a considerable degree of success, to bring together all the major points and factors to make a successful hunting trip. Mr. Merrill spent 36 years in the field as a state game warden and ranger and has drawn upon his experiences and those of others to compile a rather comprehensive how-to-do-it type of hunting and camping book.

In the 14 chapters are tips on where to go for a hunt or just an outing, planning a hunting trip, selection of weapons, how to dress, and the know-how of hunting upland game, waterfowl, and big game.

This book leans heavily to illustrations and pictures of Remington and Browning firearms but fails to mention the reliable and popular Model 70 Winchester rifle and the old Winchester 94, as well as the Model 12 Winchester shotgun. I would suggest that when the book is revised it should show photographs of lever, pump, single shot, autoloader, and double rifles and shotguns rather than illustrations of only a few types of actions.

As with most publications of this type, there are several mistakes a veteran hunter or biologist will find, such as calling a down-filled sleeping bag a feather bag, illustrating a pump action shotgun in place of a .22 automatic rifle, listing chukars adapted to prairie terrain in California, referring to a Llewellyn setter as a spaniel, and showing a photograph of a bighorn sheep and calling it a mountain goat. Other than these errors, the publication is a good reference for the outdoorsman.

The author's chapter on "Wilderness First Aid and Survival Techniques" is well written and explains how to care for the many types of injuries that can happen while in the back country.

For one who wants and needs a handy reference for all occasions of outdoor hunting activities, this publication can be recommended.—*Harold T. Harper.*

The Life of Rivers and Streams

By Robert L. Usinger; McGraw-Hill Book Co., New York, 1967; 232 p., profusely illustrated. $4.95.

This book is another of the *Our Living World of Nature* series, and contains most of the good and bad features that seem to be characteristic of these books. The photographs are again superb, but the format continues to suffer by having as many as five pages of photographs and extensive captions interrupting a train of thought.

The text reflects the fact that this book is directed toward the average layman. Even so, I feel that the author underestimates the intelligence of his audience, since he feels it is necessary to explain where a fish's gills are, and what they are for. Fortunately, the bulk of the text is not written at this level and two subjects are handled particularly well. These are Odum's work on primary productivity at Silver Springs, Florida, and Needham's work on trout populations at Sagehen Creek, California. These were described at a level that both laymen and professional people would find readable and informative.

This book continues the series' format in having an extensive appendix. Sections entitled "Rivers and Streams in the National Park System", "How to Study Fresh-Water Life", "A Guide to Aquatic Insects", and "Vanishing Fishes" are contained herein. A glossary, a bibliography, and an index complete the book.

The book's low price goes a long way in making up for its shortcomings, which compared to the high quality of the abundant photographs, seem rather minor.—*Franklin G. Hoover.*

Wildfowl 19

Edited by G. V. T. Matthews and M. A. Ogilvie; Wildfowl Trust, Slimbridge, Gloucestershire, England, 1968; 172 p., illustrated. 17/6d ($2.50) plus postage, paper.

This publication continues the fine reports that the Wildfowl Trust has published annually under the title *Wildfowl Trust Annual Report*. Only the title has been changed; otherwise, the publication would have been the 19th annual report. The title change should make the publication more readily available at libraries as a reference source.

There are 18 articles concerning waterfowl that cover a variety of subject matter, so that there should be something of interest for every waterfowl worker. The articles are illustrated with good photographs and drawings and Peter Scott has again rendered one of his excellent paintings for the cover.—*Frank M. Kozlik.*

Backyard Bandits, Including California Raccoons and Other Exciting Patio Visitors

By David D. Oliphant, Jr.; Naturegraph Publishers, Healdsburg, Calif., 1968; 139 p., illustrated. $3.95 cloth, $1.95 paper.

As one can surmise from the title of this 139-page booklet, this addition to the Naturegraph series is not a technical publication. It is not meant to be.

The author and his wife, living in the Oakland-Berkeley hills, share with the reader their 30 years of experiences with "urban-dwelling" wildlife. These wild animals include raccoons, striped and spotted skunks, opossums, gray foxes, bobcats, mountain lions, and other interesting mammals.

The accounts of their experiences illustrate that wild animals can coexist with man in a metropolitan area, provided they are supplied protection and a place in which to live. In doing so, they enrich the lives of those with whom they associate. One wonders from reading the book if they are not better adapted to urban living than we. The book is recommended reading to the many people who make inquiry about how they can provide for their backyard wild pets.—*Howard R. Leach.*

Ten-Year Index to the Journal of Wildlife Management (Volumes 21–30, 1957–1966)

By Thomas G. Scott, Marthanne B. Norgren, and W. Scott Overton; The Wildlife Society, 3900 Wisconsin Ave., N. W., Washington, D.C. 20016, 1967; vi + 234 p. $4 paper.

This reviewer is pleased that *The Wildlife Society* continues to publish multiyear indexes to its official journal. Although various retrieval services, bibliographies, and periodic compilations of abstracts serve a useful function, multiyear indexes to widely-read journals provide an unduplicated rapid means of locating articles and information about various subjects.

This index follows the general pattern of previous indexes. The main entries provide an inventory of authors, organisms, geographic locations of investigations, and subject categories. A useful list of main subject-category entries and main divisions under techniques precedes the index. In the index, common and scientific names of organisms are listed and cross-referenced.

There are various ways of organizing an index. Whatever organization is employed, numerous arbitrary judgments are involved. Of most importance, the user should be able to find the information he seeks in minimum time. This the present index accomplishes.—*Leo Shapovalov.*

Multilingual Dictionary of Fish and Fish Products: Dictionnaire Multilingue des Poissons et Produits de la Pêche

Prepared by the Organization for Economic Co-operation and Development; Fishing News (Books) Ltd., London, 1968; 448 p. £7 10s. 0d. + postage 5s.

J. J. Waterman of the Torrey Research Station, Aberdeen, Scotland, and the Organization for Economic Co-operation and Development, headquartered in Paris, are to be credited with a rather remarkable accomplishment in the production of this dictionary. Mr. Waterman compiled a preliminary list, which was then circulated by O.E.C.D. to 43 fishery experts in 19 member countries, who helped to complete the manuscript.

The dictionary consists of two parts: (1) a main part of 1,117 numbered items with descriptions in English and French (under the basic Latin) and the equivalents for the main headings in further languages, and (2) separate indices for each of the 16 languages, including one of scientific names.

The other languages incorporated are German, Danish, Spanish, Greek, Italian, Icelandic, Japanese, Norwegian, Dutch (Flemish), Portuguese, Swedish, Turkish, and Yugoslavian (Serbo-Croatian). An interesting feature is the use of the international code letters for automobiles to specify the 13 languages used in addition to English, French, and Latin. Blank spaces are provided after these code letters in instances of missing names, so that readers who know such names can write them in.

Descriptions of processing methods and essential details of the method of manufacture are provided for the many fish products listed, so that the dictionary fulfills a useful commercial purpose as well as being an excellent reference for fishery workers.

Probably because of the lack of contributors from South and Central America, some common fishes and fish products from countries there are missing. Also, obviously difficult to accomplish, the incorporation of Russian equivalents would have increased considerably the value of the dictionary. Nonetheless, it remains an extremely important contribution.—*Leo Shapovalov.*

Further Studies of Alaska Sockeye Salmon

Edited by Robert L. Burgner; University of Washington, Seattle, 1968; v + 267 p., illustrated. $3.60 paper.

Six reports by graduate students comprise this second volume of a series devoted to research on sockeye salmon conducted by the Fisheries Research Institute of the University of Washington. The titles of the reports and brief descriptions of some of the work are as follows: (i) "A Comparison of the Food of Sockeye Salmon Fry and Threespine Sticklebacks in the Wood River Lakes"; (ii) "Distribution and Growth of Sockeye Salmon Fry in Lake Aleknagik, Alaska, During the Summer of 1962" (Samples for indices of abundance, distribution, and growth of sockeye salmon fry in Lake Aleknagik were taken by beach seine, otter trawl, and tow net. Reproductions of echograms are given to illustrate the distribution of fry in the lake.); (iii) "Identification of Adult Sockeye Salmon Groups in the Chignik River System by Lacustrine Scale Measurement, Time of Entry, and Time and Location of Spawning"; (iv) "On the Use of Otoliths of Sockeye Salmon for Age Determination" (A method of determining the age of individual spawners from otoliths was developed and its validity tested.); (v) "Physical Environment and Egg Development in a Mainland Beach Area and an Island Beach Area of Iliamna Lake"; and (vi) "Surveys of Sockeye Salmon Spawning Populations in the Nushagak District, Bristol Bay, Alaska, 1946–1958".

The reports are essentially separate entities and could have been published independently. They are grouped here simply because they are part of the research program of the Fisheries Research Institute.

Although the mesh measurement method of the nets used by the first two studies is not specified, the descriptions of equipment are generally quite good. An impressive number of tables, figures, and references accompanies each report. The methods and results should be helpful in developing research and management programs for many other species.—*John W. Emig.*

The Fishes of New Guinea

By Ian S. R. Munro; Department of Agriculture, Stock and Fisheries, Port Moresby, New Guinea, 1967; xxxvii + 651 p. + 6 color and 78 black-and-white plates. $14.50.

The stated purpose of this volume is "to provide a reasonably simplified means of identification of any fish likely to be found in or around the mainland of the territory and its surrounding island groups. It brings together under a single cover descriptions, illustrations and identification keys to all the marine, brackish and fresh water fishes . . ." Its production entailed more than a decade of work by Ian Munro extracting records from over 200 publications dating back to the work of Lacépède in 1803, examining numerous existing fish collections, and making additional collections throughout the New Guinea area.

For each of the 1,096 species there is a brief technical diagnosis which provides standard counts and measurements, details about distinctive features, information on body and fin coloration, an approximation of maximum length, and notation of general habitat. A common name is provided for each species, and there is a citation for the original description.

The identification keys that are sprinkled throughout the text will prove extremely helpful, but they are not infallible: mistakes of previous workers often have been perpetuated, additions to the fauna are bound to turn up, and the known fauna is not so well understood that all species can be keyed out successfully.

Other than citations to the original descriptions, no references have been included in this volume. The ichthyologist who wishes to delve deeper into the fauna must obtain as companion volumes the check list entitled "The fishes of the New Guinea region" (Papua and New Guinea Agric. Jour., 10: 97–339, 1958) and "Additions to the fish fauna of New Guinea" (Papua and New Guinea Agric. Jour., 16 : 141–186, 1964).

The 78 black-and-white plates illustrate 1,056 species and are mostly miniature reproductions of published figures, but some are originals. Many of the 76 species illustrations in color are based upon the superb watercolors of Australian painter George Coates. Most appear to have been included for their rainbow-hued beauty, and since their colors have been reproduced quite well, they are a welcome addition to a worthwhile volume.—*John E. Fitch.*

The Salt Water Aquarium Manual

By Robert J. Valenti; Aquarium Stock Company, New York, 1968; 162 p., profusely illustrated. $6.95.

The author has attempted to provide a basic reference and guide for the amateur saltwater aquarium hobbyist. He emphasizes a natural environment, including the presence of algae and bacteria, as contrasted with the superclean saltwater aquarium frequently recommended for beginners.

The book provides a very good treatment of the basic considerations involved in the selection and establishment of a marine aquarium. The author has been careful to explain the reasons for his many suggestions on how to avoid the disasters which befall so many beginning saltwater aquarists. His treatment of water chemistry, temperatures, light, and filtration is good and easily understood. The book provides sketchy treatment of marine plants, marine invertebrates, and marine fishes. The chapter on marine fishes has some very helpful hints on keeping them successfully in an aquarium.

Many of the photographs are of very poor quality, and the author's style of presenting one thought and then supplying several counter or qualifying thoughts is disconcerting in that it tends to confuse the reader.

The book should be helpful as a guide to the beginning saltwater aquarist and also to the biologist who may find it necessary to occasionally hold saltwater fish for bioassays or other studies.—*J. C. Fraser.*

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